

DEPARTMENT OF THE ARMY TECHNICAL MANUAL

DEPARTMENT OF THE AIR FORCE TECHNICAL ORDER

TM 11-4700

TO 16-1-106

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**ELECTRICAL
INDICATING AND MEASURING
INSTRUMENTS
REPAIR INSTRUCTIONS**

*DEPARTMENTS OF THE ARMY AND THE AIR FORCE
MAY 1952*

TM 11-4700/TO 16-1-106

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DEPARTMENTS OF THE ARMY AND
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WARNING

Voltages and currents of sufficient amplitude to cause injury or death may be encountered in the repair and calibration of electrical indicating and measuring instruments. Repair personnel should be extremely careful when performing work of this type, and they should be trained in the application of artificial respiration and other first aid measures.

CHAPTER 1

INTRODUCTION

Section I. GENERAL

1. Purpose

The purpose of this manual is: first, to review the fundamental principles of magnetism and electromagnetism, and the application of these principles to electrical measuring instruments; and second, to prescribe practices, procedures, and techniques to be followed in the electrical and mechanical repair and calibration of such instruments.

2. Scope

Chapter 1 contains information on the use of the manual and general references. Chapter 2 covers the principles and theory of electrical meters and measuring instruments. Chapter 3 deals with the principles of operation, meter maintenance, and maintenance equipment for electrical instruments. Chapter 4 contains calibration information on specific equipments, and chapter 5 information on the calibration of exposure meters. Appendix I contains a glossary, and appendix II contains miscellaneous information, such as mathematical formulas.

3. References

For information on basic electrical theory, refer to TM 11-661 and TM 11-681. For information on the installation, operation, and func-

tioning of any standard equipment covered in this manual, consult the technical manual referred to in the heading of the paragraph that covers the equipment.

4. Requisitions for Repair Parts

Meter repair parts are listed in SIG 6, MK-3/MSM-2. Requisitions for a part must cite an authorized basis, such as a specific T/O&E, T/A, SIG 7&8, SIG 7-8-10, SIG 10, list of allowances of expendable material, or another authorized supply basis.

5. Standard Used for Testing

Instruments that have an accuracy within .5 percent to .1 percent of full-scale value are classed as secondary standards, and are used normally as working standards against which the switchboard and panel type instruments found in Signal Corps equipments are calibrated. Meter Test Equipment AN/GSM-1B (pars. 41 through 47) is classed as a working standard. Subsequent references in this manual to a *working standard* refer to Meter Test Equipment AN/GSM-1B or its equivalent. When the calibration charts furnished with the equipment are used, accuracy may be brought to .25 percent.

Section II. TEST EQUIPMENT AND TOOLS

6. Test Equipment

Meter Test Equipment AN/GSM-1B (pars. 41 through 47) is essential to the repair and calibration of electrical meters. The equipment consists of the following components:

- a. Meter Test Set TS-682/GSM-1.
- b. Magnet Charger TS-336A/GSM-1.
- c. Frequency Meter FR-40/GSM-1.
- d. Decade Resistor TS-679/U.
- e. Test Set I-49.

- f. Multimeter TS-352/U.
- g. Tube Tester I-177-().
- h. Tube Socket Adapter Kit MX-949()/U.
- i. Resistance Bridge ZM-9()/U.

7. Tools

An instrument repair section should be equipped with Instrument Tool Equipment TK-3/MSM-2. Each electrical instrument repair-

man should have available Tool Equipment TK-21/G or equivalent.

8. Meter Repair Parts

The instrument repair section should be equipped with Meter Repair Parts Kit MK-3/MSM-2. This kit contains complete movements, hairsprings, jewel screws, multipliers, shunts, thermocouples, and assorted hardware sufficient to repair most of the meters.

CHAPTER 2

OPERATING PRINCIPLES AND GENERAL CONSTRUCTIONAL DETAILS

Section I. OPERATING PRINCIPLES

9. General

The electrical meters, such as voltmeters and ammeters, used in measuring instruments are generally adaptations or modifications of the galvanometer, which presents indications caused by the movement of free electrons along a conductor. The galvanometer detects the existence, relative intensity, and sometimes the polarity of small currents.

10. Basic Principles

Galvanometers and practically all other electrical measuring instruments depend on electromagnetism for their operation. Magnetism and electromagnetism will be discussed only briefly in the following paragraphs. Electrical instrument repairmen, however, must have a thorough working knowledge of the fundamentals of electricity in general. For a detailed presentation of electrical fundamentals, refer to TM 11-661 and TM 11-681.

11. Magnets

Magnets may be divided into two general classes:

a. Permanent magnets, which are made of hardened steel or other special alloys, retain their magnetism indefinitely.

b. Electromagnets, which are made of soft iron surrounded by a coil, depend on the flow of electric current through the surrounding coil to produce the magnetic effect. The magnetism exists only while the current is flowing.

12. Magnetic Fields

A magnetic field is assumed to consist of invisible lines, called *lines of force* (fig. 1).

a. When a material is magnetized, lines of force appear to emerge from some parts of the material and enter other parts. The part from which the lines of force emerge is called the *north pole*, and the part into which the lines of force enter is called the *south pole*.

b. When studying the effects of lines of force, keep the following laws in mind:

- (1) For magnetic forces of attraction, the lines of force always tend to contract in the manner of rubber bands. This is not true for magnetic forces of repulsion.
- (2) Lines of force never cross each other.
- (3) Each line of force around a magnet forms a complete loop, north to south externally and south to north internally.
- (4) Whenever possible, external lines of force around a magnet follow a path through a magnetic material, rather than through air or through a nonmagnetic material.
- (5) No known insulating material prevents the passage of magnetic lines of force.

13. Basic Law of Magnetism

The basic law of magnetism is: *Like magnetic poles repel each other, and unlike mag-*

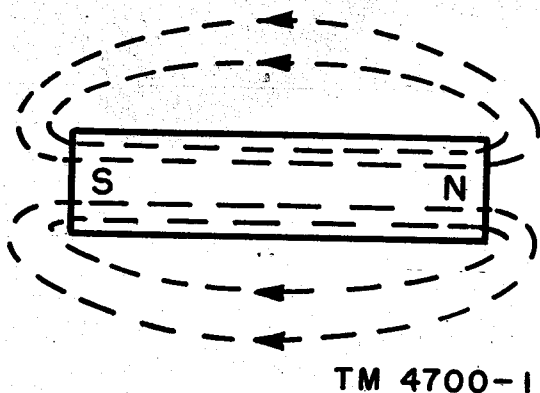
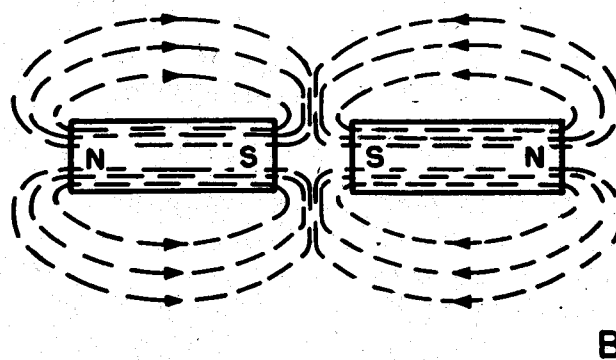
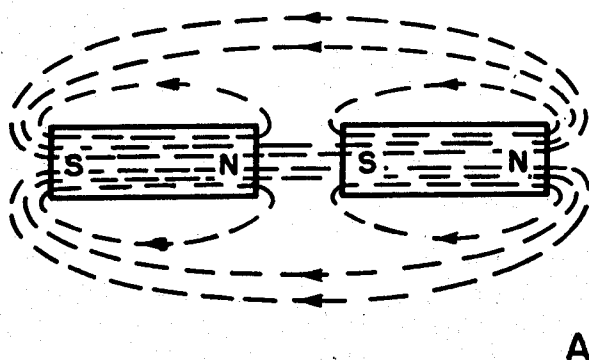


Figure 1. Magnetic field around a bar magnet.

netic poles attract each other. Figure 2 shows the effect on the lines of force around two magnets when like poles are adjacent and when unlike poles are adjacent. The magnets in A of figure 2, are forced together to shorten the gap between them because the lines of force tend to contract. In B of figure 2, the two magnets remain separated because the lines of force cannot cross each other; in other words, they repel each other.



TM 4700-2

Figure 2. Lines of force around adjacent magnets.

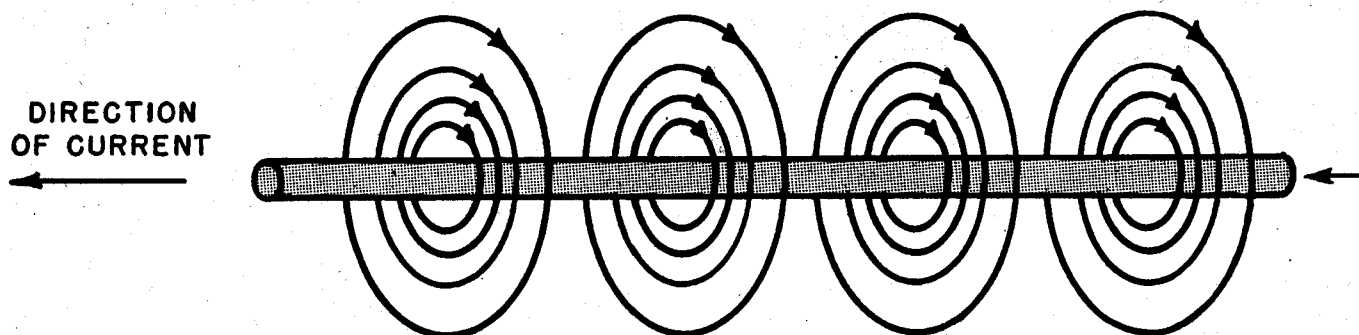


Figure 3. Magnetic field around a straight conductor.

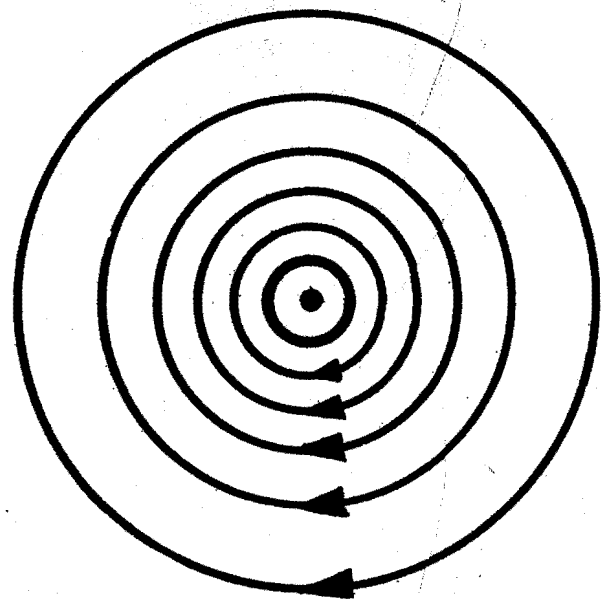
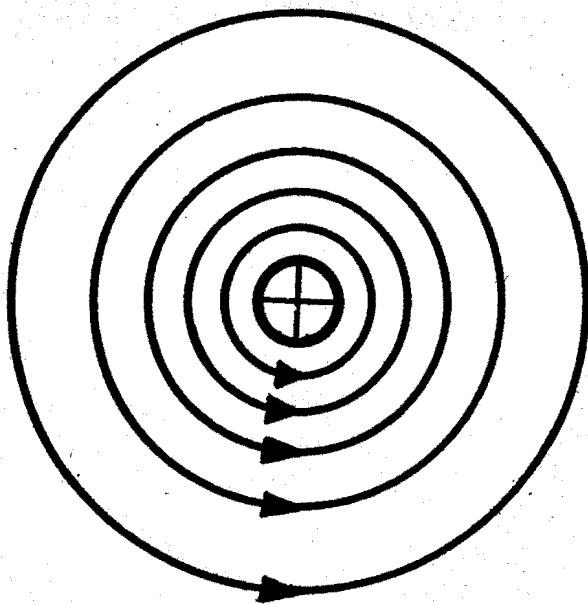
14. Electromagnetism

If a wire is passed through a magnetic field, an electric current is generated and flows along the wire through a circuit connected between the ends of the wire. If a wire is connected to a source of emf (electromotive force), a magnetic field will exist around the wire (fig. 3). This magnetic field is circular (fig. 4). The plus sign of the conductor in figure 4 indicates that the current is flowing into the page, away from the reader.

Note. The direction of current flow, as presented in this technical manual, is that of electron flow, which is from negative to positive.

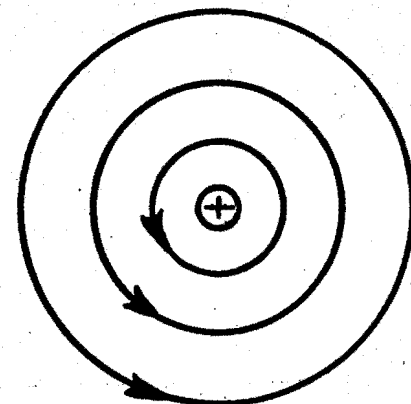
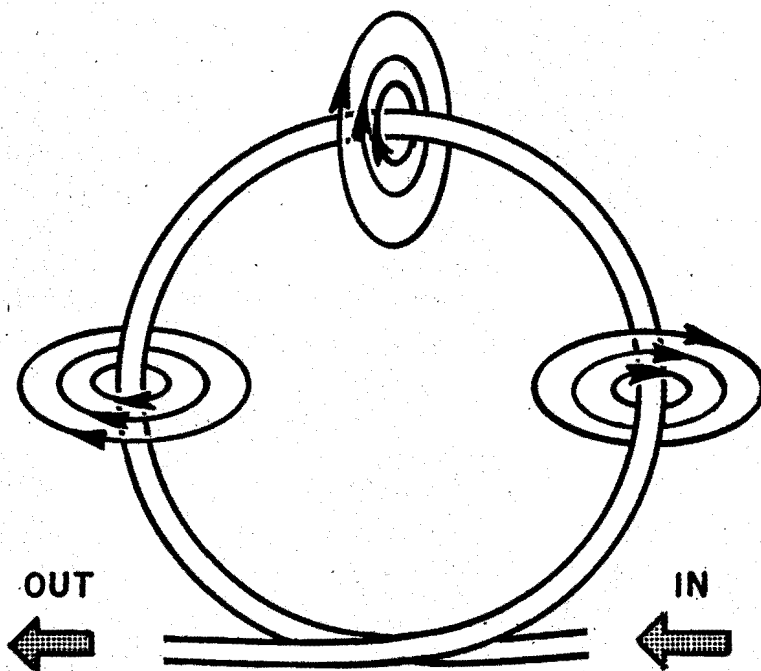
15. Solenoids

When a wire is formed in the shape of a loop and a current passes through the wire, magnetic North and South Poles are established. The lines of force produced by the energized loop have the same characteristics as those of a permanent magnet (fig. 5). When several of these loops are placed together to form a coil and the coil is energized, the strength of the magnetic field is greatly increased (fig. 6). Such a coil is known as a solenoid.



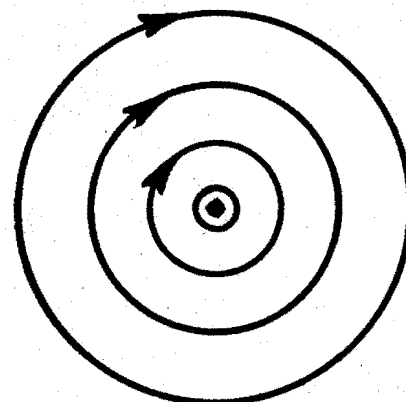
TM 4700-4

Figure 4. End views of field of force about a circular conductor.



S

N



CROSS SECTION OF
LOOP

TM 4700-5

Figure 5. Magnetic field produced by a single loop of wire.

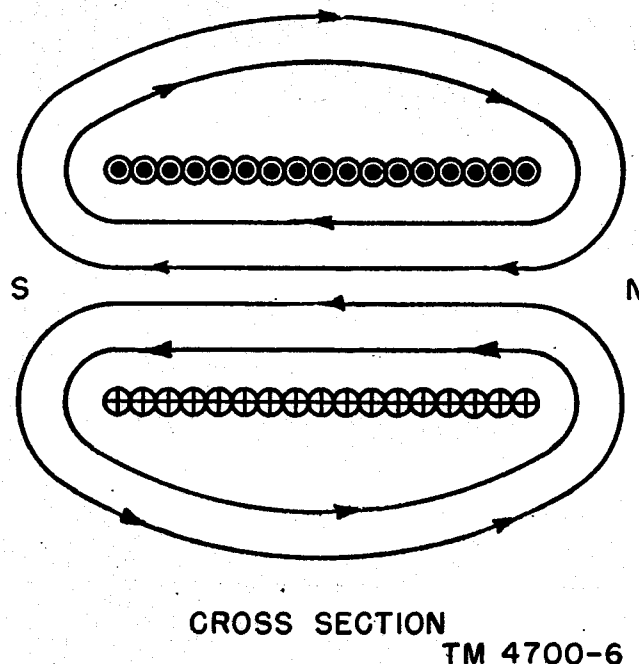
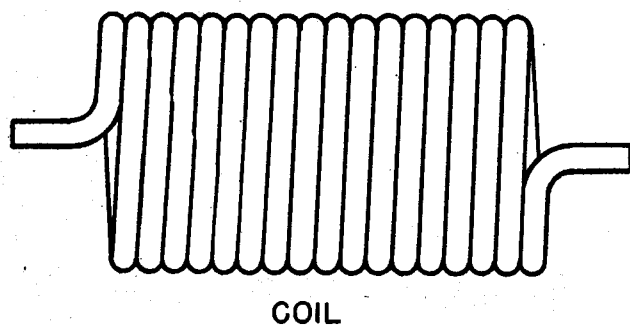


Figure 6. Solenoid.

16. Electromagnets

An electromagnet is formed when turns of a current-carrying conductor are wound around an iron core (fig. 7). The magnetic field is concentrated in the iron core, particularly at the poles. An electromagnet has all the qualities of a permanent bar magnet, and all the rules of magnetism that apply to permanent magnets also apply to electromagnets. The poles of an electromagnet attract unlike poles and repel

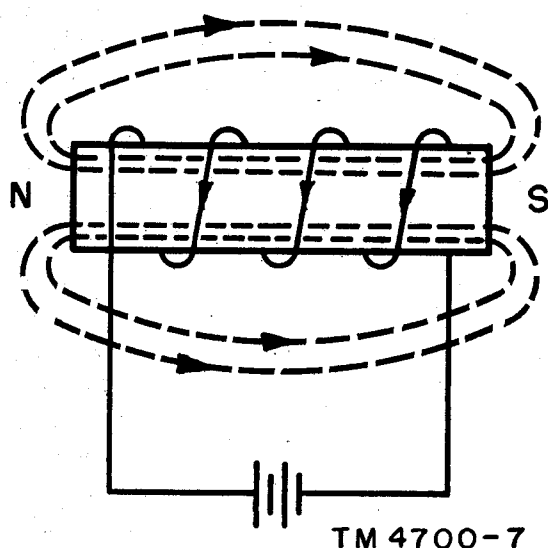


Figure 7. Electromagnet.

like poles of permanent magnets or other electromagnets.

17. Magnetic Shielding

There is no known insulator for magnetic lines of force. These lines pass through such nonmagnetic materials as glass, paper, wood, and copper without appreciable loss of strength. However, it is often desirable to shield galvanometers and other electrical measuring instruments from the earth's magnetic field and from stray fields produced by generators, current-carrying conductors, and similar sources, since these foreign fields cause incorrect instrument readings. Because iron is a good conductor for magnetic lines of force, an iron shell surrounding the instrument will bypass practically all stray lines of force, and prevent them from affecting the sensitive recording or measuring mechanism of the instrument (fig. 8). For the more sensitive instruments, three or four shells may be used, with air spaces between them. Although perfect shielding cannot be obtained by this method, it is usually possible to reduce the stray field within the shell to a negligible value.

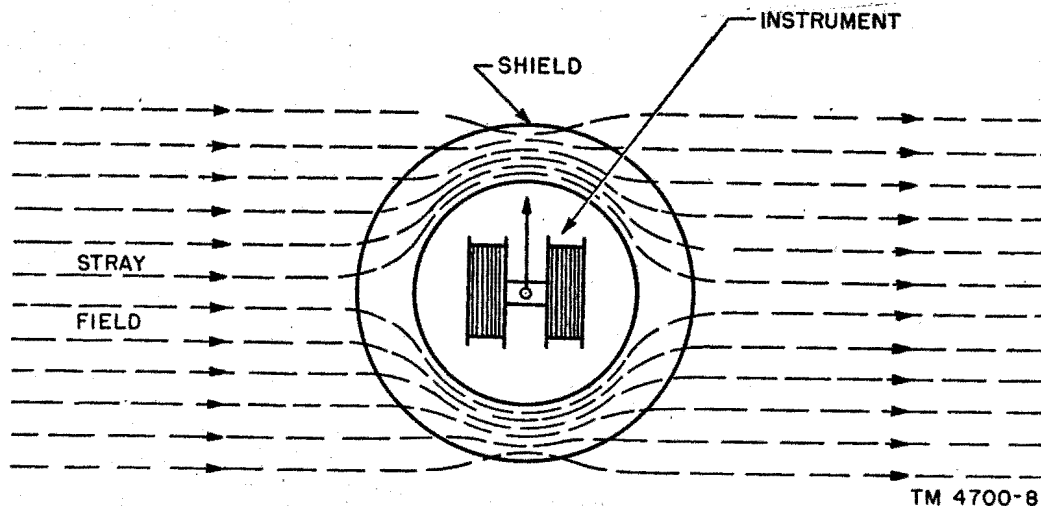


Figure 8. Effect of magnetic shielding.

Section II. GENERAL CONSTRUCTIONAL DETAILS

18. General

Electrical measuring instruments are tools which make use of magnetism and electromagnetism to provide essential information about electrical circuits. Several types of instrument are designed for use in d-c (direct-current) circuits, and others for use in a-c (alternating-current) circuits. Some instruments are designed for use in the laboratory and others for use in the field. The power consumption of any electrical measuring instrument should be small, in comparison with the power available in the circuit under test. In general, an a-c voltmeter or ammeter uses several times as much power as a comparable d-c instrument. The remainder of this section contains information on the construction and applications of the types of instrument generally used for test purposes and as component parts of communication equipment used in the field.

19. Components Parts

a. General. An electrical measuring instrument usually consists of the following parts: moving element with attached pointer; stationary element; controlling element; moving-element mounting; and bearings and case, including terminals, dials, and screws. Each part has a specific purpose and is designed to accomplish this purpose as efficiently as possible. A description of each part and its function is given in *b* through *g* below.

b. Moving Element. The moving element is a part so mounted that it will rotate when energized by the current to be measured or by a proportional part of that current. The rotation causes a pointer affixed to the movable element to move across a scale, which is usually calibrated. The moving element may be one of two types: a moving coil, as used in the D'Arsonval and the electro-dynamometer instruments; or a moving iron vane, as used in the magnetic-vane instrument. To keep the moving element light in weight and as free from inertia as possible when either the D'Arsonval or the electro-dynamometer instrument is used as an ammeter, the larger part of the current to be measured usually is shunted around the moving coil; when the instrument is used as a voltmeter, the current is kept at a low value by a high resistance in series with the meter movement.

c. Stationary Element. The stationary element may be either a permanent magnet or a coil. The function of the stationary element is to furnish a magnetic field to react with the magnetic field set up around the moving element or, as in some instruments, to attract a moving element made of a magnetic material.

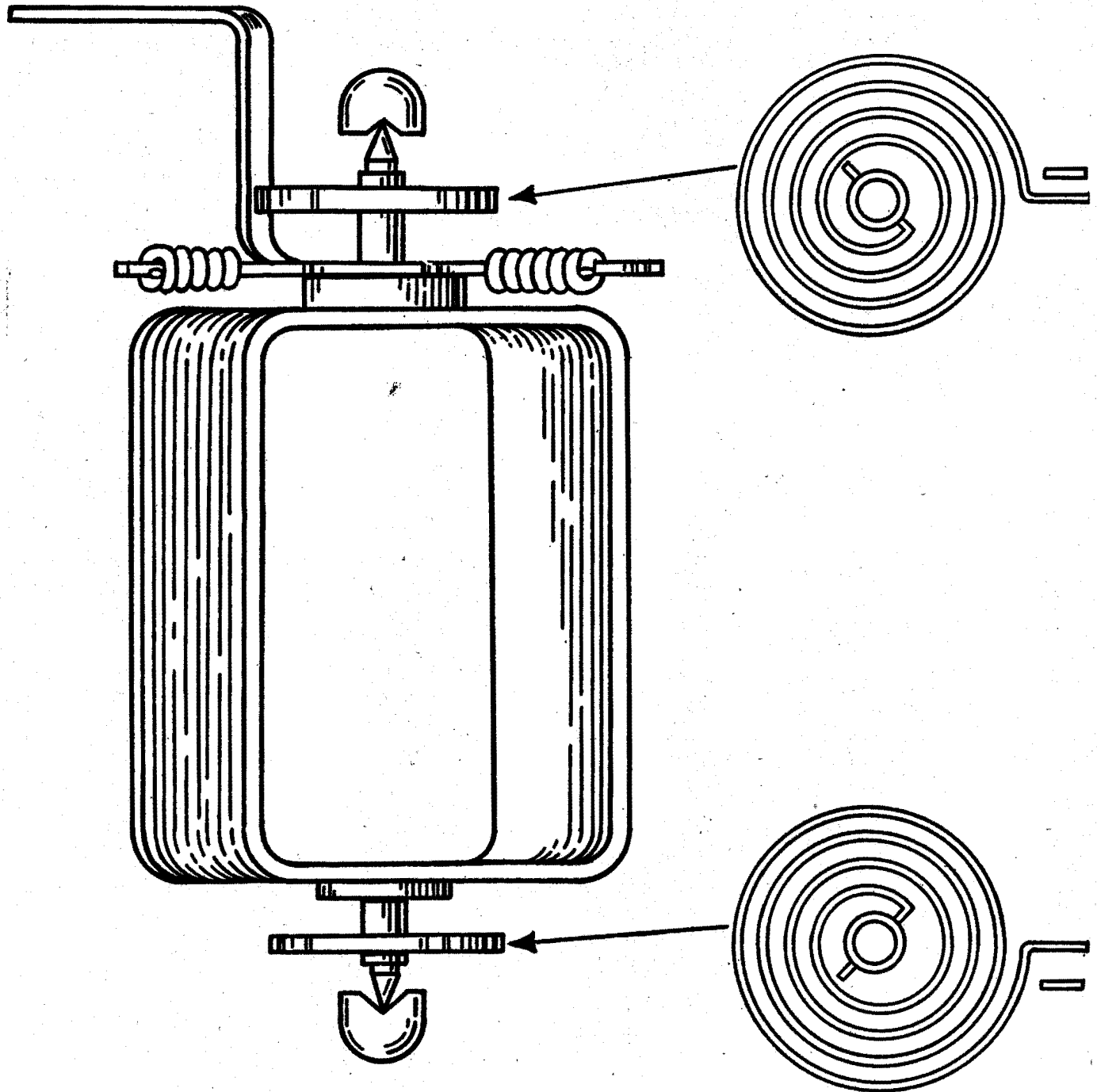
d. Controlling Element. The controlling element is usually a spring or springs (fig. 9). The main function of the controlling element is to provide a counter, or restoring, force that will increase as the moving element turns and bring the pointer to rest at some position on the scale in accordance with the value of the quantity

being measured. Two springs, wound in opposite directions, generally are used to compensate for variations caused by expansion and contraction of the spring material due to temperature changes. The controlling element is made of nonmagnetic material, which serves as a conductor to the moving coil in some types of instruments.

e. Moving-Element Mounting. A shaft with

very hard pivot points is used to carry the moving element. The pivot points are fitted into bearings so that the moving element can rotate with very little friction. In a new type of mounting, the pivot points are reversed and the bearings are inside the moving-coil assembly (fig. 38).

f. Bearings. The bearings are highly polished jewels, such as sapphires, synthetic jewels or,



TM 4700-9

Figure 9. Moving-coil mechanism.

in some cases, very hard glass. Each bearing usually is round in shape with a conical depression into which a pivot point fits, and is set in threaded nuts to permit adjustment for end play. The radius of the depression in each jewel is greater than the radius of the pivot point to limit the area of contact surface and to provide a bearing which, when operated dry, probably has the lowest constant friction value of any known type of bearing.

g. Damping Devices.

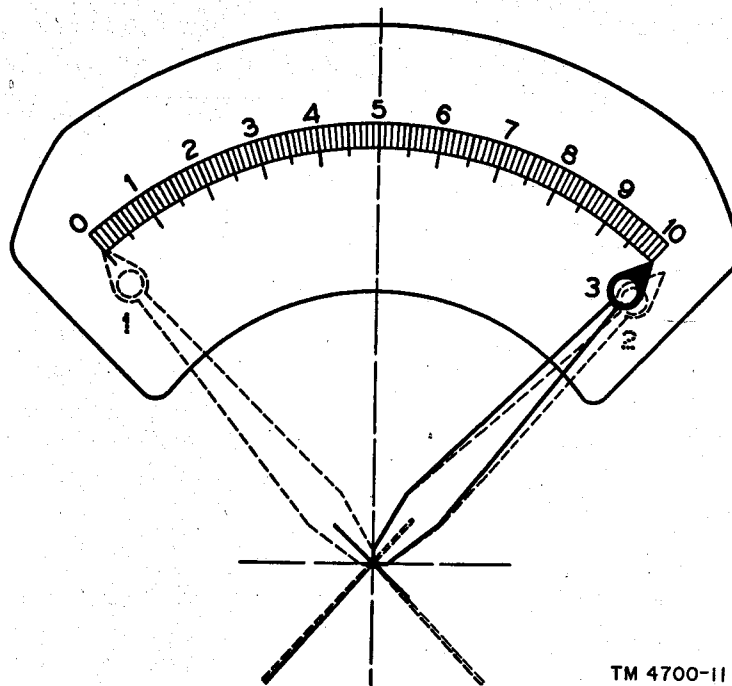
- (1) *General.* Damping is a term applied to methods used to bring the pointer of an electrical indicating instrument quickly to rest after it has been set in motion, so that the value of the quantity being measured can be read without loss of time. The method of damping may be electrical (magnetic), mechanical (air damping), or a combination of the two.
- (2) *Damping of d-c instruments.* Damping in D'Arsonval type instruments (par. 20) may be accomplished by either of two methods, both electrical. Generally it is accomplished by winding the moving coil on a light, aluminum frame. Eddy currents, caused by motion of the moving coil in the permanent-magnet field, are set up in the frame. The field produced by the eddy currents interacts with the field of the permanent magnet and opposes the motion of the coil so that it comes to rest quickly. The second method, found in some highly sensitive meters that measure voltages, uses resistance in series and parallel with the moving coil. Moving coils of this type are not wound on metallic frames, because the weight must be kept to a minimum. Proper adjustment of the resistance produces constant damping, but there is a slight decrease in the sensitivity of the instrument. The damping of an instrument should be just sufficient to limit the overshoot of the moving system so that the pointer comes to rest

after not more than one or two oscillations (fig. 10).

- (3) *Damping of a-c instruments.* In a-c instruments, magnetic damping, air damping, or a combination of both is used.
 - (a) As in d-c instruments, when the damping is magnetic ((2) above) the reaction of the field on the field of a permanent magnet is used, but the actual arrangement of the device is somewhat different. A small aluminum disk, which is mounted on the shaft of the moving element, moves between the poles of a small permanent magnet. The motion sets up eddy currents in the disk and creates a field which interacts with the field of the permanent magnet to oppose the motion of the moving element and bring it quickly to a stop.
 - (b) When air damping is used, a vane attached to the shaft of the moving element moves in a closed air chamber to give a retarding effect (fig. 11). The air chamber should be closed, and the vane should nearly touch the walls of the chamber, if the damping is to be effective.

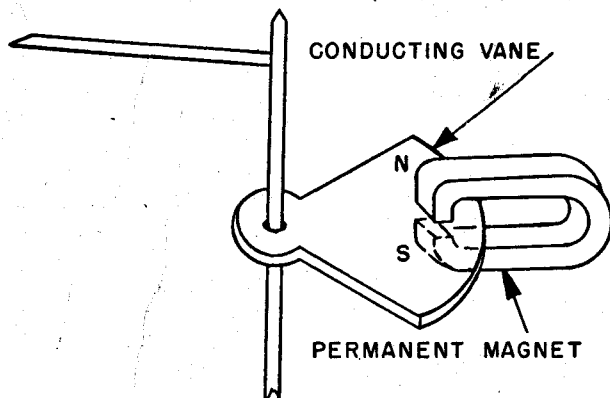
h. Case, Terminals, Dial, and Screws.

- (1) An instrument case securely houses the meter mechanism to protect it from mechanical injury and exposure. Cases are made of either metal or non-metallic materials, such as hard woods, molded compounds, or a combination of both. A glass window is set in the case so that movement of the pointer across the calibrated scale may be observed.
- (2) The terminals, which are made of materials that have very low electrical resistance, conduct the required current into and away from the meter. They are comparatively large, and are machined and threaded accurately. With proper washers and nuts, they

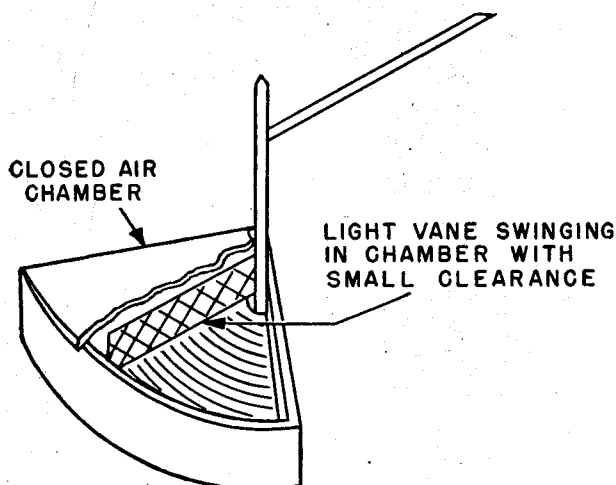


TM 4700-11

Figure 10. Meter action with correct damping. (Numbers refer to pointer positions).



WHEN VANE MOVES, EDDY CURRENTS ARE PRODUCED IN IT, TENDING TO OPPOSE MOTION



WHEN VANE MOVES, MOTION TENDS TO BE OPPOSED BY CONSTRICTION OF AIR IN CHAMBER

TM 4700-12

Figure 11. Magnetic and air damping.

provide a low-resistance positive-contact path.

- (3) The dial usually is made of light aluminum with a white enameled surface. Ordinarily the scale is marked on the dial in units for which the instrument is calibrated. In addition, the following markings generally are found on the dial: the type of instrument (a-c or d-c); the unit of measurement for which the instrument is calibrated; and, in the case of small panel meters, the model number and the manufacturer's name.
- (4) The screws, three or four in number, are small, fine-threaded, and usually flat or oval-headed. They are used to secure the meter housing to the meter base.

i. Shunts, Series Resistors, and Multipliers.

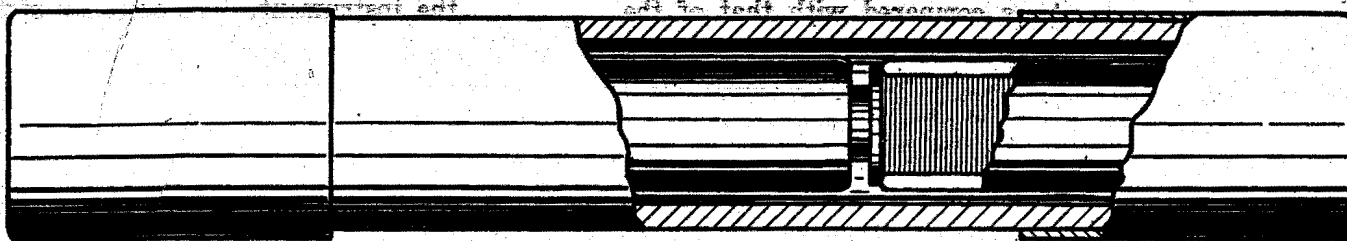
- (1) A meter shunt is a resistor connected in parallel with the meter circuit to bypass the major portion of the current being measured. The value of the shunt connected across the moving coil or instrument depends on the resistance of the moving coil or instru-

ment, as compared with that of the shunt. Ammeter shunts are adjusted by the manufacturer to have a specific mv (millivolt) drop at rated full-load current. Ammeters or millivoltmeters that use shunts usually are calibrated to read in amperes the rated current of the shunt. The resistance of the leads is taken into consideration when the instrument is calibrated.

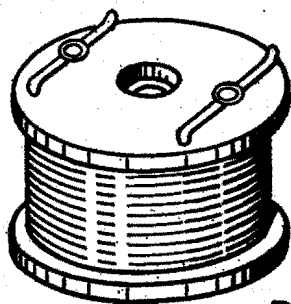
- (a) Shunts usually are made of materials whose resistance is not greatly affected by temperature changes. The material must be such that no voltage resulting from galvanic action (chemical reaction between dissimilar metals in contact with each other) will be produced when the shunt is connected to the copper conductor. Either temperature changes or galvanic action in shunt material will introduce errors in meter readings.
- (b) Ammeter shunts must be constructed so that they will not be injured by abnormal currents of short duration, and ample provision must be made for the dissipation of heat due to continuous operation. The resistance of a well-made shunt will not change with use if it is handled carefully. If an ammeter is to be placed in a circuit, determine before making connections whether the shunt is contained in the instrument or whether an external shunt is required. In calibrating an instrument with an external shunt, be sure that the terminal connections are tight.
- (2) A series resistor, or multiplier, is a resistance unit used with voltmeters and millivoltmeters to limit the value of current to that required for full-scale deflection at the rated voltage of

the instrument. The accuracy of the resistor must be as high as possible, usually higher than that of the instrument. Special high-resistance wire (nichrome or similar alloy) with a low temperature coefficient is used to reduce temperature errors and keep the resistor unit as small as possible.

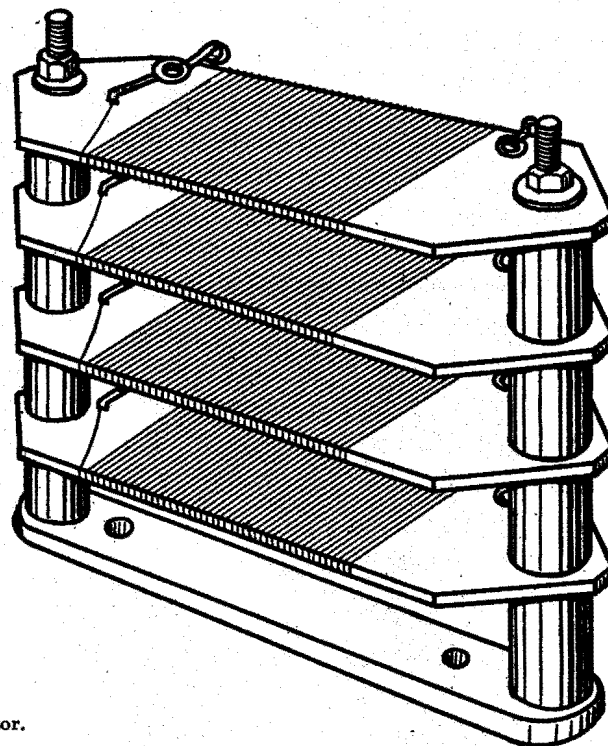
- (3) To increase the range of the instrument, multipliers of the proper resistances usually are connected in series with the meter. For example, to double the range of a 150-volt voltmeter with a total resistance of 150,000 ohms, a multiplier with a resistance of 150,000 ohms must be connected in series with the voltmeter.
- (4) Individual resistance units for each desired range, or single resistance units tapped at the correct values, may be used. A single instrument supplied with a convenient means of switching to the desired range is very useful for general test purposes.
- (5) Resistors may be contained within the meter or inclosed in external resistance boxes. External resistors are especially useful when the resistance unit required generates more heat than the instrument case can dissipate. Three types of resistors used to increase the range of meters are shown in figure 12.
 - (a) A tubular resistor is wax-filled, hermetically sealed, and electrostatically shielded to insure long life at high voltages in humid or salty atmospheres (A of fig. 12).
 - (b) A small, compact spool resistor is used in the more sensitive self-contained meters (B of fig. 12).
 - (c) A card-type resistor is used in larger instruments (C of fig. 12).



A



B

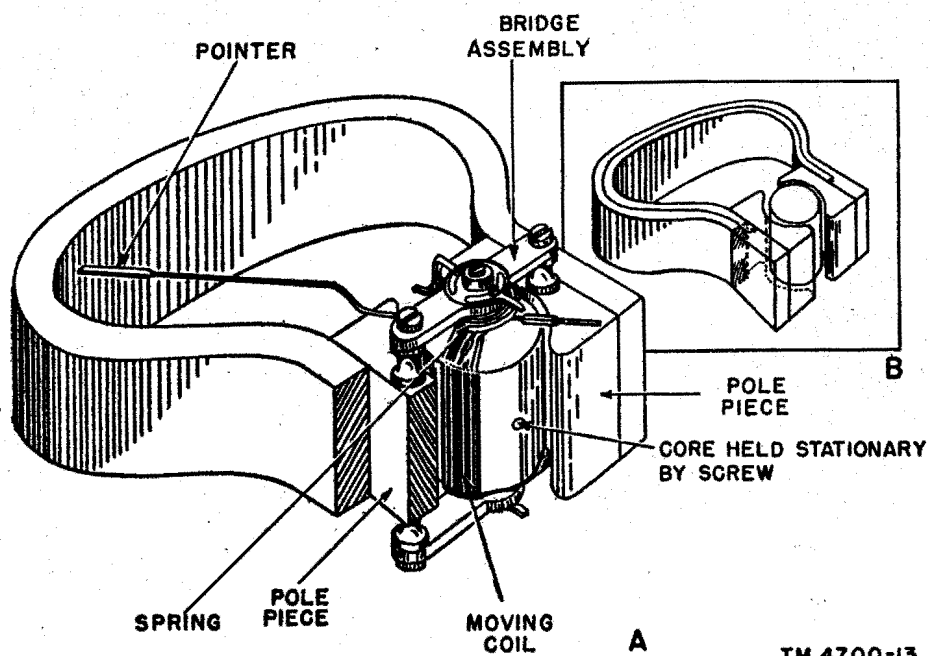


C

- A. Tubular resistor.
- B. Spool resistor.
- C. Card-type resistor.

Figure 12. Types of resistor used to increase range of meters.

TM 4700-10.



TM 4700-13

Figure 13. D'Arsonval movement.

Section III. DIRECT-CURRENT INSTRUMENTS

20. Construction and Theory of Operation

The operation of the D'Arsonval, or permanent-magnet, moving-coil type meter depends on the interaction between magnetic lines of force set up by the moving coil and those set up by the permanent magnet. When current flows through the moving coil, a field is set up around the moving coil. The field of the permanent magnet remains constant, while the field of the moving coil changes with the change in current flow. The coil and permanent magnet are placed in the instrument so that north poles are adjacent and south poles are adjacent. Since like poles are repelled and unlike poles are attracted, the coil, which is pivoted at its center, tends to rotate when current flows through it. The turning motion of the coil is opposed by the action of two springs, which also conduct current to and from the coil. The turning force of the coil depends on the strength of the magnetic field generated by the coil; this strength is proportional to the value of current flowing through the coil. When the turning force is equal to the opposition of the springs, the pointer stops moving across the scale, and a reading may be obtained. The pole pieces of the magnet form a circular air gap, which insures a uniform field and even-scale distribution. Figure 13 illustrates the permanent-magnet, moving-coil mechanism and shows the magnet, the pointer, the spring, the moving coil, the bridge assembly (fig. 15), and the position of the pole pieces in relation to the moving coil. One side of the magnet has been cut away to show the position of the moving coil when the pointer is in zero position.

21. Ammeters and Millivoltmeters

It is not common practice to send more than .1 ampere through a moving coil. A shunt must be provided (par. 19i) to accommodate larger currents. D-c millivoltmeters used with shunts generally require up to 25 ma (milliamperes), depending on the type of instrument, for full-scale deflection at 30 to 200 mv (fig. 14). Since the field supplied by the permanent magnet is unidirectional, the instruments described in this paragraph are suitable for use on dc only. If

60-cycle ac is impressed on such an instrument, the pointer vibrates about the scale zero point. Figure 15 illustrates a disassembled d-c milliammeter with a range of 0 to 500 ma, and indicates the nomenclature of each part.

22. Voltmeters

To convert a milliammeter into a d-c voltmeter, a resistance is inserted in the instrument circuit (fig. 16). This resistance limits the current to a value that permits full-scale deflection of the pointer when the maximum rated voltage is applied. For example, to change an ammeter with a full-scale rating of 10 ma (.01 ampere) to a voltmeter with a full-scale rating of 150 volts, it would be necessary to connect a resistance of $150/0.01$, or 15,000 ohms, in series with the meter movement. The 15,000-ohms resistance will reduce the current to .01 ampere when 150 volts are connected across the meter

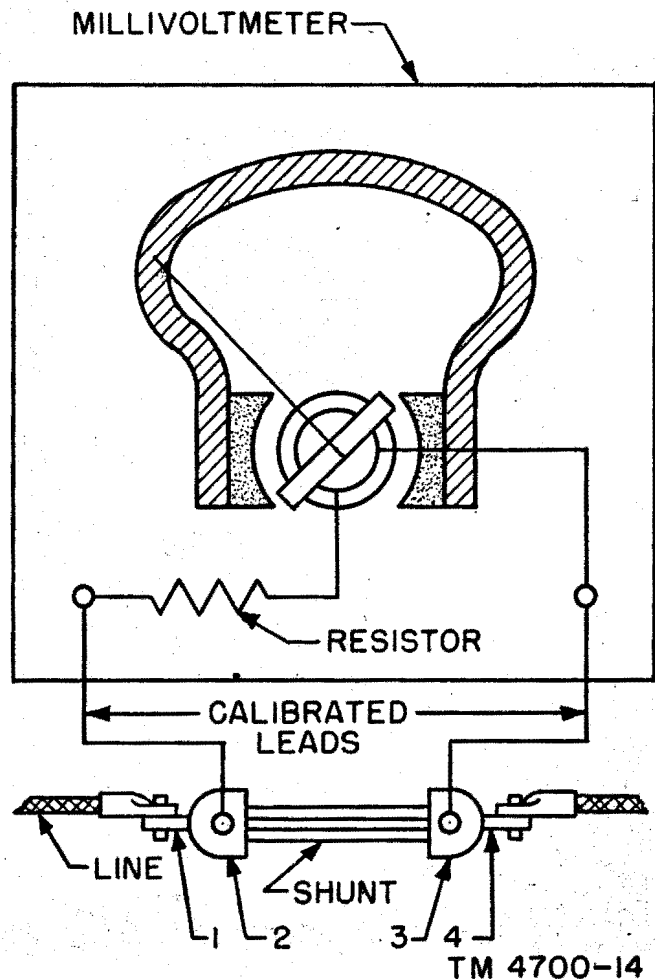


Figure 14. Millivoltmeter with shunt.

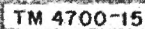


Figure 15. Disassembled d-c milliammeter.

1. Cover assembly.
2. Cover screw.
3. Scale-plate screw.
4. Scale-plate lockwasher.
5. Scale plate.
6. Ground clip.
7. Element assembly with pole pieces.
- 8, 9. Magnet clamp and screw.
10. Magnet.
11. Base assembly with shunt.
12. Terminal-stud lockwasher.
13. Terminal-stud nut.
- 14, 15. Lockwasher and nut for magnet clamp screw.
16. Screw for holding pole piece to base.
- 17-19. Screw, washer, and fiber washer for top bridge.
20. Pointer stop assembly.
21. Top bridge fiber bushing.
- 22, 23. Top jewel screw and nut.
24. Top bridge assembly.
25. Armature assembly.
26. Core.
27. Pole piece assembly.
- 28-30. Hexagonal nut, washer, and square nut for core.
31. Core screw.
32. Lower regulator.
33. Spring washer.
- 34, 35. Bottom jewel nut and screw.

Figure 15—Continued.

terminals. However, since the milliammeter moving coil itself has about 20-ohms resistance, it is necessary to add only 14,980 ohms. The resistor should be constructed so that it will not be affected by ordinary changes in temperature.

Section IV. ALTERNATING-CURRENT INSTRUMENTS

23. General

Instruments used for the measurement of ac usually differ in several respects from those used in d-c circuits. If the a-c instrument is to operate on the principle of a moving coil in a magnetic field, the magnetic field in which the coil moves must reverse at the same instant that the current in the coil reverses so that the pointer will continue to deflect in the same direc-

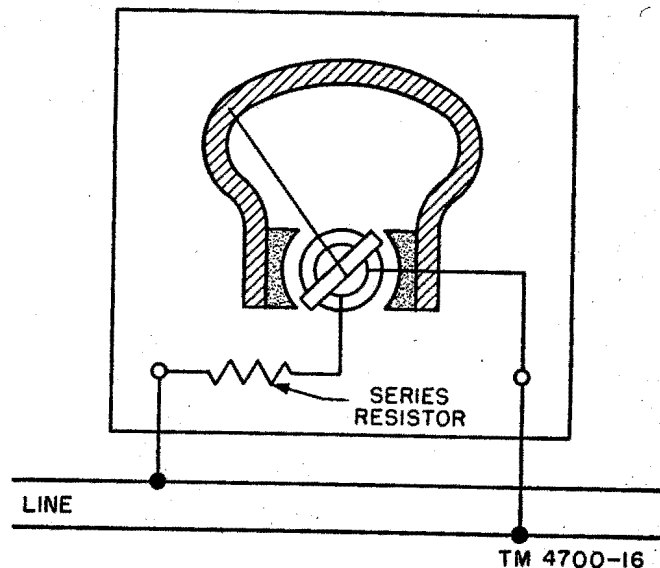


Figure 16. Voltmeter (millimeter with a series resistor).

Although resistance of the moving coil varies with temperature changes, the high value of the resistor as compared with the resistance value of the moving system compensates for any variations. When a given voltage is applied, there is only a negligible variation in current flowing through the moving system due to temperature changes. Several different ranges are obtained by using separate resistors known as multipliers (par. 19i(3)), or by tapping off at various points on the same resistor. Most voltmeters require a very small value of current for operation. A common type of voltmeter, rated at 500 volts, requires about 1 ma for full-scale deflection. Since its resistance must be equal to $500/0.001$ or 500,000 ohms, and full-scale reading is 500, the instrument has a resistance of $500,000/500$ or 1,000 ohms per volt. Certain types of voltmeter have a resistance as high as 20,000 ohms per volt.

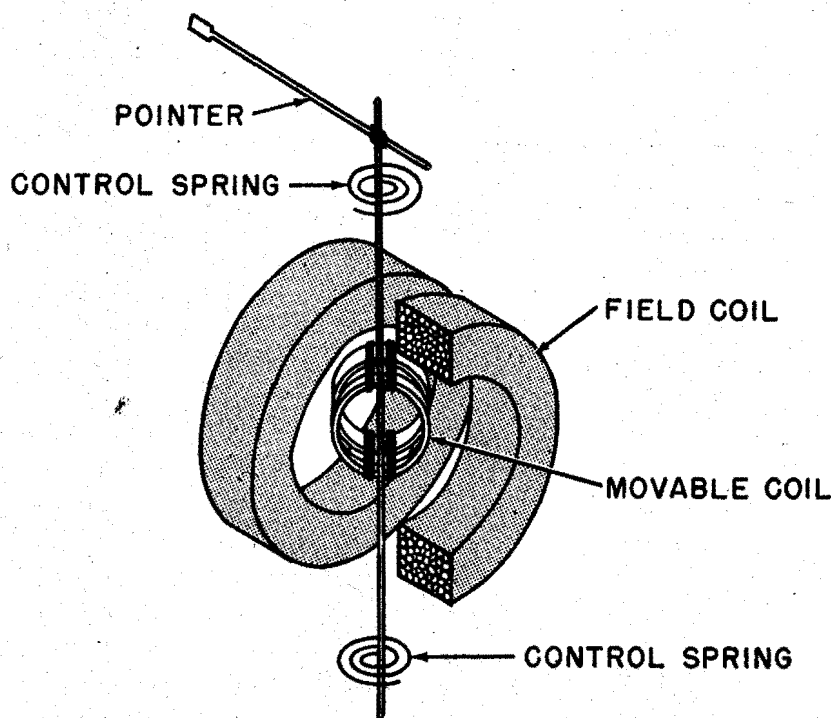
tion. Since a reversing field cannot be produced by a permanent magnet, the design of the a-c instrument must differ from that of the d-c instrument. A-c measuring instruments used in the field may be divided into four types: electro-dynamometer, moving-iron vane, rectifier, and thermocouple. The hot-wire type of meter is not used extensively and will not be discussed. Also of interest are the frequency meter, used

to indicate the frequency of a-c power-supply circuits and generating equipment, and the vacuum-tube voltmeter, used extensively in radio testing and servicing.

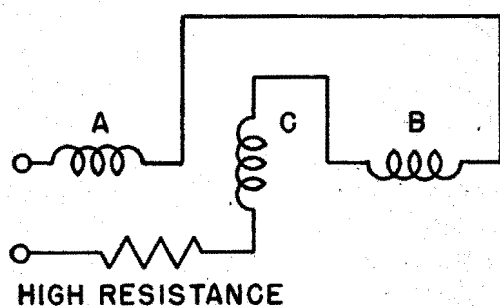
24. Electrodynamometer-Type Meter

a. *Principle of Operation.* The electrodynamic-type meter, also called the electrodynamic type, depends on the reaction between a fixed coil and a moving coil. In the usual form, a single coil rotates within two parallel fixed coils (A of fig. 17). The current flowing through

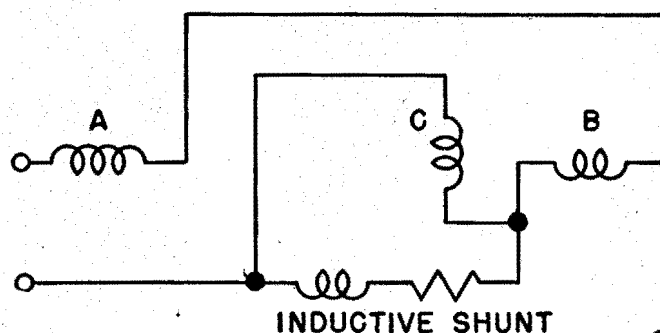
the fixed coils and the moving coil sets up magnetic fields about these coils. Because of the force exerted by the control springs, the axis of the magnetic field around the moving coil (a line passing through the center of the coil from end to end) is not parallel to the axis of the magnetic field around the fixed coils. The two magnetic fields attempt to align themselves in accordance with the law of magnetic poles; the turning force is proportional to the strength of the two magnetic fields, and the strength of the two magnetic fields, in turn, depends on the value of current flowing through the coils. A



A



B



C

- A. Basic electrodynamic-type instrument.
- B. Used as voltmeter.
- C. Used as ammeter.

Figure 17. Electrodynamometer type meter.

TM 4700-17

moving coil cannot carry heavy current unless special means are provided for conducting the current to and from the coil. The current required for voltmeters usually is not more than .1 ampere. This current can be conducted to and from the moving coil through the control springs. B of figure 17, shows the circuit arrangement for an electrodynamicometer-type instrument used as a voltmeter. In the case of ammeters, special construction is necessary because of the large currents. The stationary coils A and B (C of fig. 17) generally are built to carry 5 amperes, and the moving coil C (C of fig. 17) carries only a small part of this current. In series with the stationary coils is an inductive shunt, which has the same ratio of resistance as the moving coil connected across the terminals of the shunt. Since the power factor of the shunt is the same as that of the moving coil, the division of current between them is independent of frequency, and the instrument is, therefore, reasonably accurate at commercial frequencies.

b. Application (Wattmeter).

(1) It is often necessary to check the power consumption of various types of electrical equipment. In d-c circuits this is comparatively simple; the unit of power, the *watt*, is the product of the voltage and the current (P (in watts) = E (in volts) $\times$ I (in amperes)). In a-c circuits, this relationship is true only when voltage and current are in phase. Since this in-phase condition seldom exists in practice, some other method must be used; the electrodynamicometer principle is applied, particularly in the portable type of wattmeter.

(2) If an electrodynamicometer-type wattmeter is connected in a circuit (fig. 18), the current in the fixed coils is the instantaneous load current, and the current in the movable coil is proportional to the instantaneous line voltage. Since the turning force on the moving coil is equal to the product of the current and the voltage, the instru-

ment indicates the amount of power used, and the scale of the instrument can be calibrated in watts. When current and voltage are in phase, the turning force exerted on the moving element is positive in direction. When current and voltage are not in phase, the turning force is negative in direction at certain intervals, but the instrument pointer continues to deflect in a positive direction. The pointer assumes a position dependent on the average value of the turning force over a period of time, because the action of the moving element is not fast enough

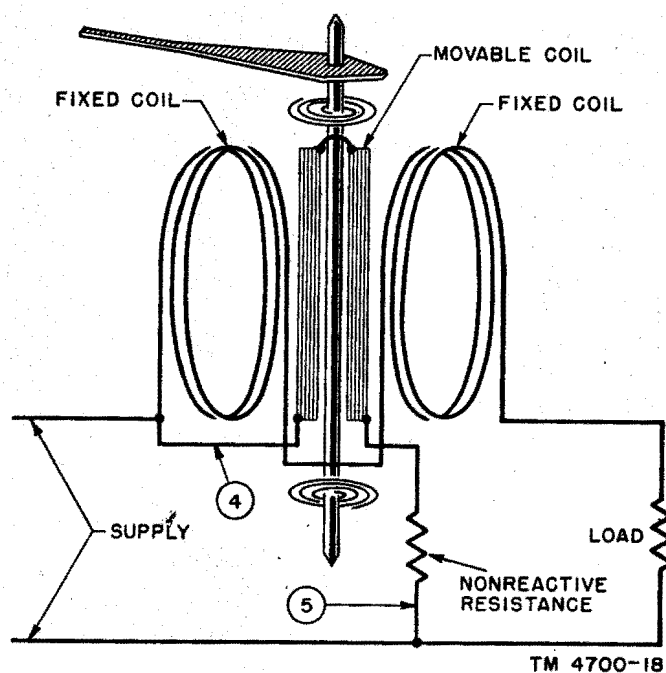


Figure 18. Electrodynamicometer-type wattmeter.

to respond to each 60-cycle impulse.

(3) Certain precautions must be observed when a wattmeter is connected in a circuit. Do not exceed the current and voltage rating specified on the dial of the instrument. Always connect the moving element or potential coil (4, fig. 18) to the side of the circuit that contains the fixed coils (current coils.) This connection keeps the moving coil at the same potential as the fixed coils

and avoids undue stress on the insulation of the coils. It helps to eliminate errors due to electrostatic forces and the possibility of reversing the potential coil with respect to the current coils.

- (4) To measure power in other than single-phase circuits, more elaborate wattmeters or a combination of wattmeters is used. Follow the circuit diagrams when they are included with such meters.

25. Moving Iron-vane Type of Meter

(figs. 19 and 20)

Originally, some instruments were designed to operate on the principle of the attraction of magnetic materials by a magnetic field. Such instruments are practically obsolete, so far as signal communication equipment is concerned, and now are used principally in inexpensive meters, such as pocket battery testers and the indicators on charging equipment for storage batteries. They have been superseded by the moving iron-vane (also called magnetic-vane), repulsion-type meter. A small strip of soft iron (3, fig. 19), bent into cylindrical shape, is mounted on a shaft (5), which is free to turn. A similar strip (2), which is approximately wedge-shaped, with a larger radius than the first strip (3), is fixed in a cylindrical coil (1). The coil is wound with fine wire and is connected in series with a high value of resistance. (If this type of instrument is to be used as an ammeter, the coil is wound with fewer turns and heavier wire.) When the instrument is connected across the line, the current through the coil is proportional to the line voltage, and the iron vane becomes magnetized. At a given instant, if the upper edges of both vanes have a north magnetic polarity, the lower edges of both vanes will have a south magnetic polarity. This like magnetic polarity at corresponding edges of the vanes will continue regardless of the direction of current flow through the coil, and the upper edges of the two vanes will repulse the lower edges. Because of their shape and position, the vanes tend to transform the repulsion into rotary motion, which turns the shaft (5) against the forces exerted by the springs (4). A pointer (6), mounted on the

shaft, moves over a graduated scale to indicate the magnitude of the voltage. The iron-vane principle has been applied to the inclined-coil type of instrument, which need not be described in detail because the major difference is in mechanical construction.

26. Rectifier Type Meter

Some instruments for a-c voltage measurement are of the permanent-magnet moving-coil type; they use auxiliary devices which permit unidirectional current to be sent through the moving coil. This current must bear a definite relationship to the quantity being measured so that the instrument scale can be marked in terms of the a-c value. A rectifier, which allows

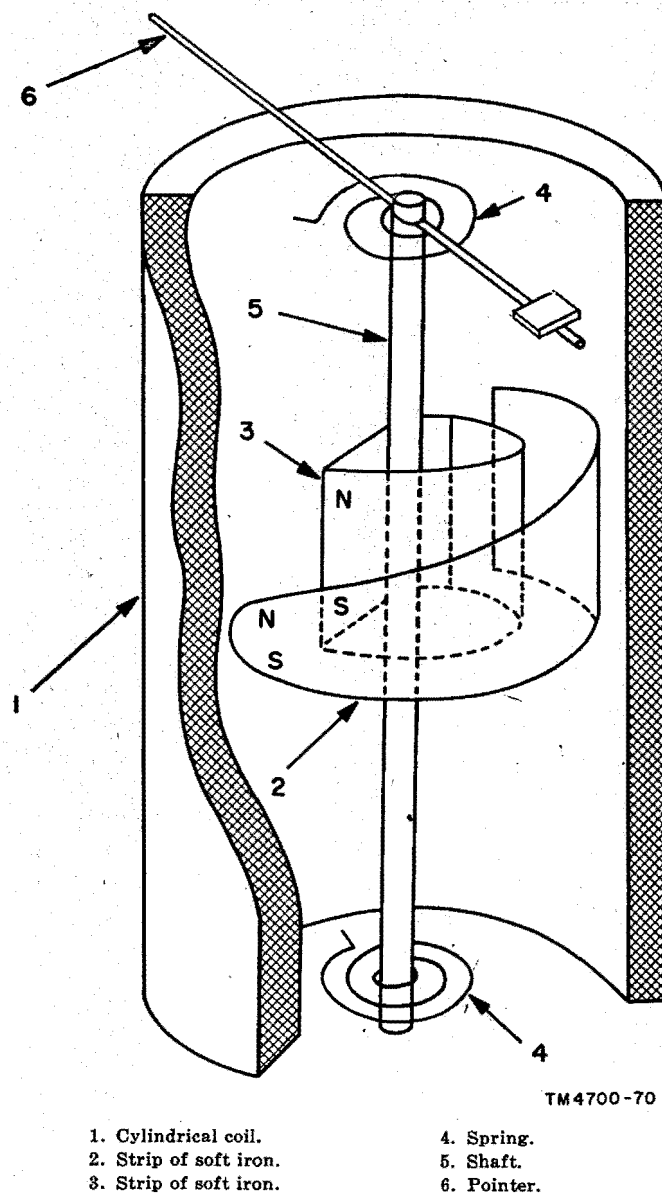


Figure 19. Moving iron-vane type meter.

the free flow of current in one direction but offers a high resistance to the flow of current in the opposite direction, generally is used to make this possible.

a. A rectifier type meter may be equipped with any one of several types of rectifying device. The most common type is the copper-oxide rectifier, which consists of one or more copper-oxide disks, each in contact with a copper disk. Current flows from the copper disk to the copper-oxide disk, but not in the reverse direction (A of fig. 21). When a voltmeter is connected in such a circuit, the current flow through the meter is as shown in D of figure 21. As the applied voltage increases, the unidirectional current through the moving coil increases. A reading which bears a definite relation to the a-c line voltage is obtained, and the meter scale can be marked in terms of a-c volts. Such a device is called a half-wave rectifier.

b. The half-wave rectifier type meter is not practical for most purposes because during the negative half of each cycle, when no current flows, the rectifier must withstand the full line voltage. Although copper-oxide plates are not well suited to withstand such inverse voltages, the difficulty can be remedied easily. A simple device, known as a bridge connection, utilizes four sets of copper-oxide plates connected in the form of a diamond. Figure 22 indicates the paths taken by the current during the positive and negative half-cycles, respectively. Since a bridge connected in this manner rectifies each half-cycle of the a-c wave, it is called a full-wave rectifier.

c. In some circuits, bridges of fewer than four copper-oxide plates are used. The operation of such circuits can be determined readily by making diagrams of the current flow for each half-cycle.

d. Permanent-magnet, moving-coil meters indicate average values. In the rectified sine wave (C of fig. 22), the average is shown by the lower line. In a-c circuits, however, the rms (root-mean-square) value indicated by the higher line generally is required, and the meter scale is calibrated in terms of the rms value. For other wave shapes the ratio is different, and therefore, rectifier type meters read rms values correctly only for the wave shape for which they are calibrated. In measuring nonsinusoidal values, such as the output of constant-voltage

transformers, the same principle holds true. Other factors to be considered when using rectifier type meters are as follows:

- (1) Since rectifier units are not 100 percent accurate, the stated accuracy of the meter usually is given as plus or minus 5 percent of the full-scale reading of the meter.
- (2) Rectifiers should not be exposed to chemical vapors, such as sulphur fumes, or to extremely high temperatures.
- (3) When a rectifier is connected to an a-c line, the load should never be removed from the rectifier until the rectifier has been disconnected from the line, because the surge of full-line voltage may damage the rectifier plates.

27. Thermionic (Vacuum-Tube) Voltmeter

An instrument has been devised to measure voltages in circuits where the consumption of a minute amount of power seriously disturbs the circuit under test. This type is widely used in the servicing and repair of signal communication equipment, such as radios and public-address systems.

a. An instrument called a VTVM (vacuum-tube voltmeter) makes possible the measurement of voltages with practically zero power consumption from the circuit under test. The VTVM uses the vacuum tube and usually a d-c milliammeter. With the necessary voltage supply, resistors, switches, and other components, an inexpensive portable instrument can be built. The high sensitivity of this instrument (large deflections of the indicating meter with minute variations of voltage input), as well as the very high accuracy obtained, makes possible electrical measurements in circuits of high impedance and very low power.

b. The most common circuit arrangements of the VTVM are variations of d-c amplifier and a-c rectifier circuits. The operation of these circuits is based on the fact that the plate current in a vacuum tube faithfully follows voltage changes at the grid of the tube. The plate current is measured on a d-c milliammeter, which is calibrated in volts. For a-c measurements,

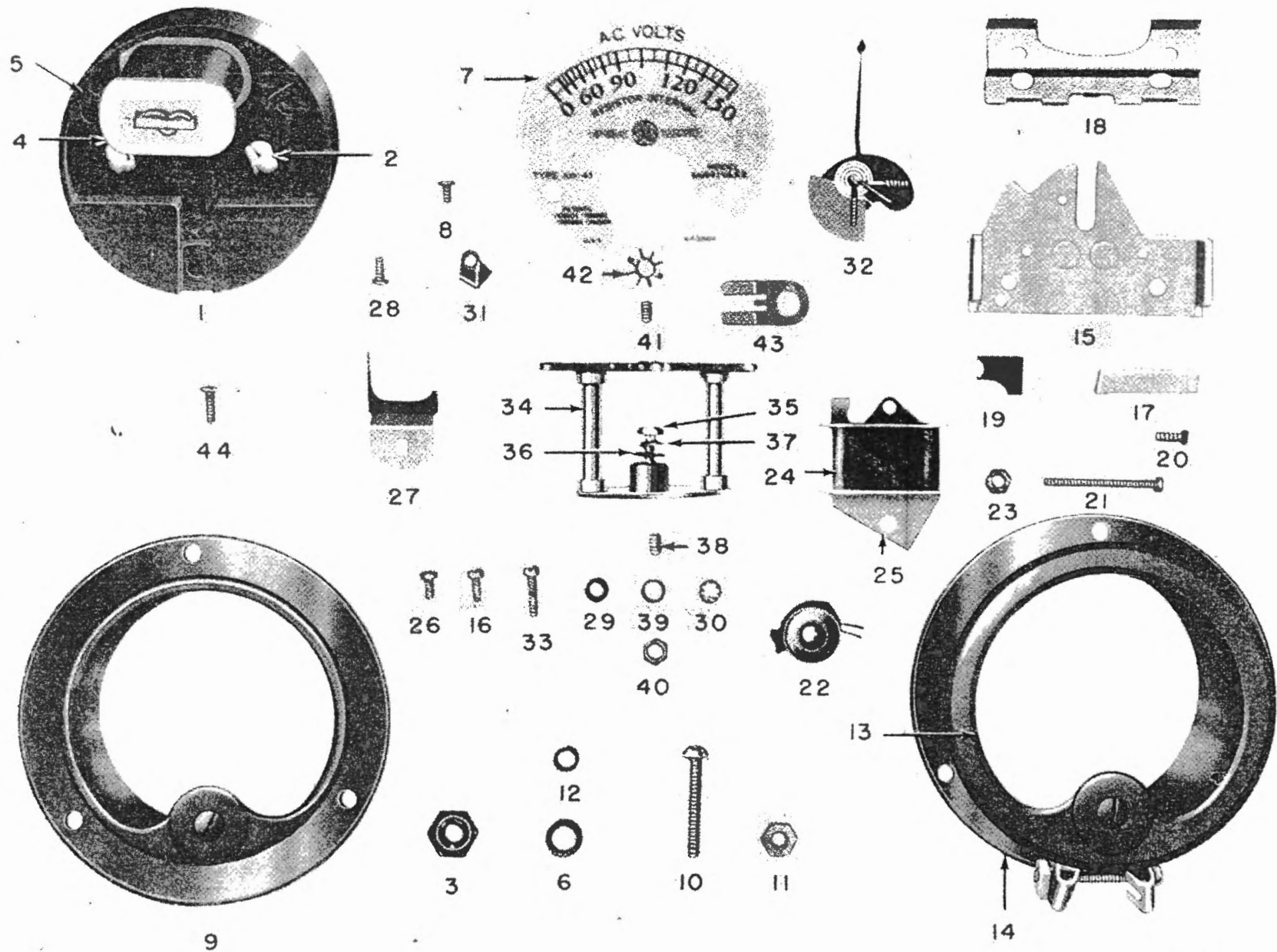


Figure 20. A-c voltmeter, moving iron-vane movement.

1. Base, complete with nut and washer for element frame.
- 2, 3. Terminal stud and nut.
4. Resistance spool, large.
- 5, 6. Screw for resistance spool and lockwasher.
7. Scale blank.
8. Scale screw.
9. Wide flange cover.
- 10-12. Mounting screw (nut and washer) for cover.
13. Narrow flange cover.
14. Clamping ring with screw and nut.
15. Magnet shield with pole piece.
16. Screw for magnet shield and pole piece.
17. Magnet.
18. Magnet clamp.
19. Magnet spacer.
20. Screw for magnet shield, clamp, and spacer.
21. Screw for magnet shield.
22. Resistance spool, small.
23. Nut for resistance spool.
24. Field coil.
- 25, 23. Field-coil shield and screw.
27. Flux distributor.
28. Flux-distributor screw.
29. Washer for screw No. 26 or No. 28.
30. Lockwasher for screw No. 26 or No. 28.
31. Adjusting strap.
32. Armature with spring.
33. Screw for armature and base.
34. Element frame.
- 35-37. Element-frame screw, washer, and lockwasher.
- 38-40. Bottom jewel screw, lockwasher, and nut.
- 41, 42. Top jewel screw and nut.
43. Zero regulator adjuster.
44. Cover screw.

Figure 20—Continued.

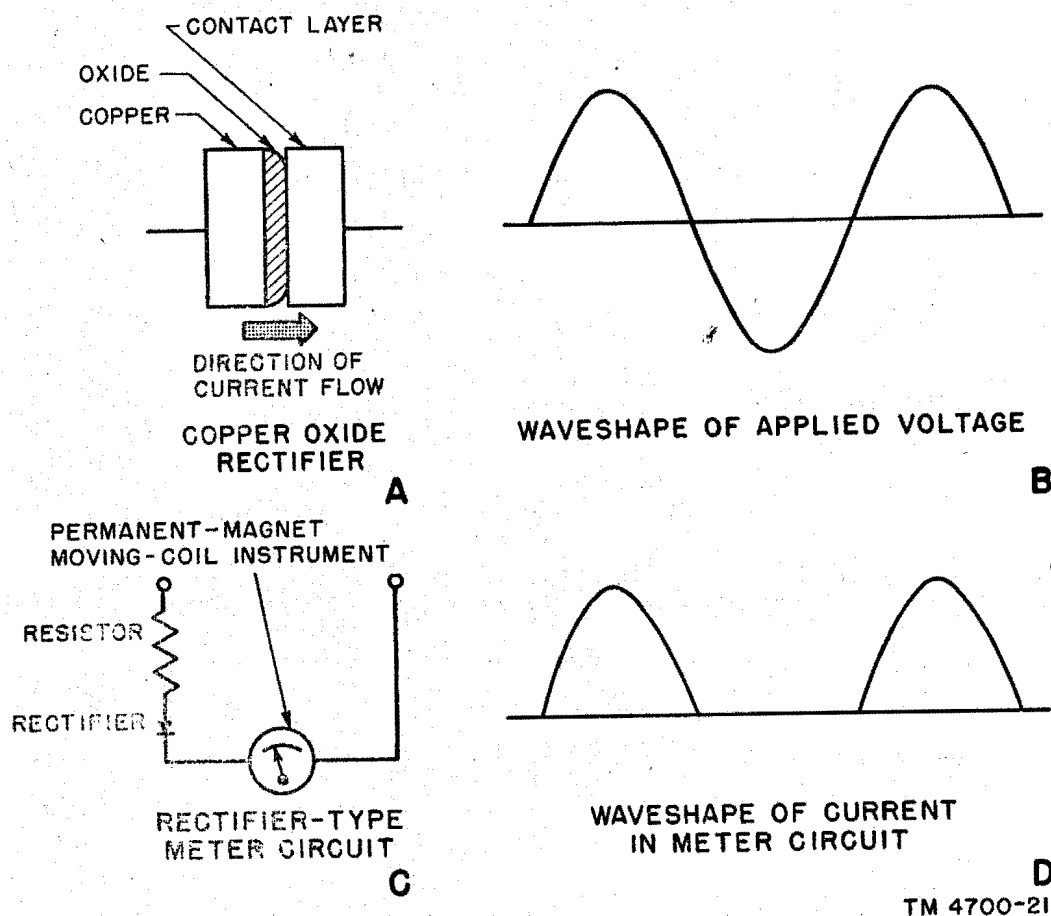
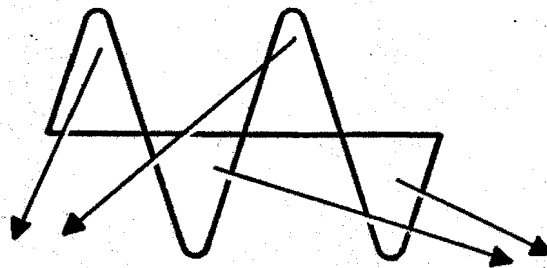
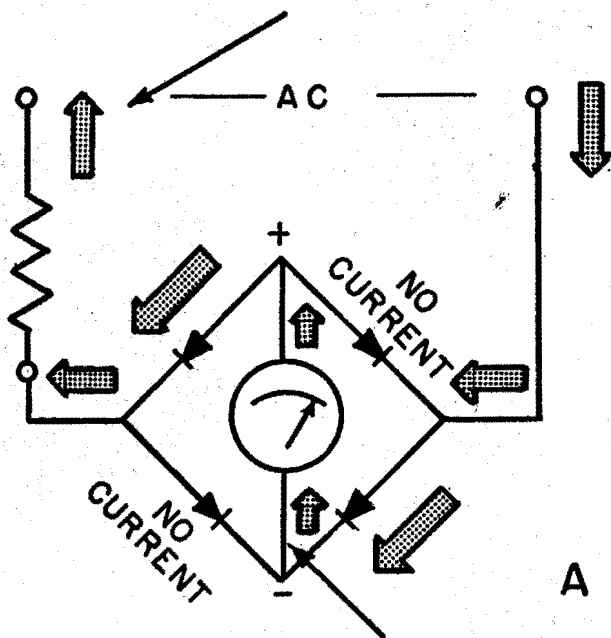


Figure 21. Half-wave copper-oxide rectifier type meter circuit.

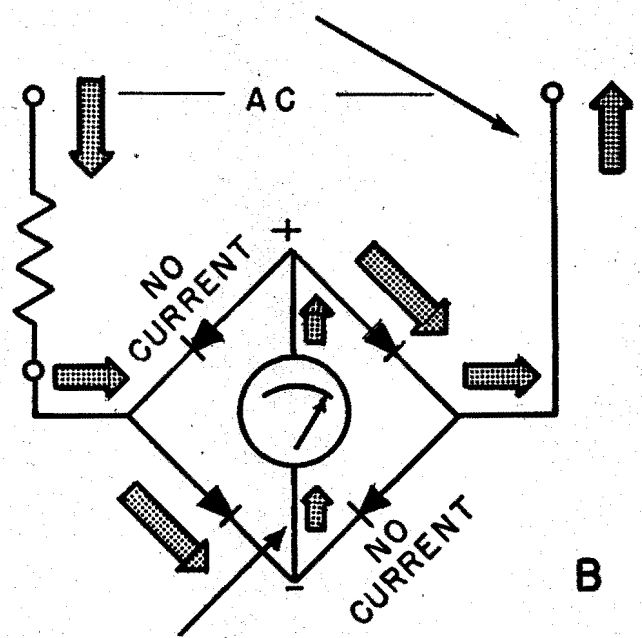


DURING THESE HALF-CYCLES
CURRENT FLOWS THROUGH
CIRCUIT IN THIS DIRECTION

DURING THESE HALF-CYCLES
CURRENT FLOWS THROUGH
CIRCUIT IN THIS DIRECTION

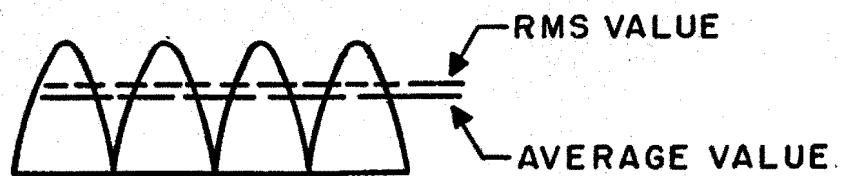


A



B

NOTE THAT INSTRUMENT CURRENT
IS ALWAYS IN SAME DIRECTION



C

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Figure 22. Circuit arrangement for full-wave rectification.

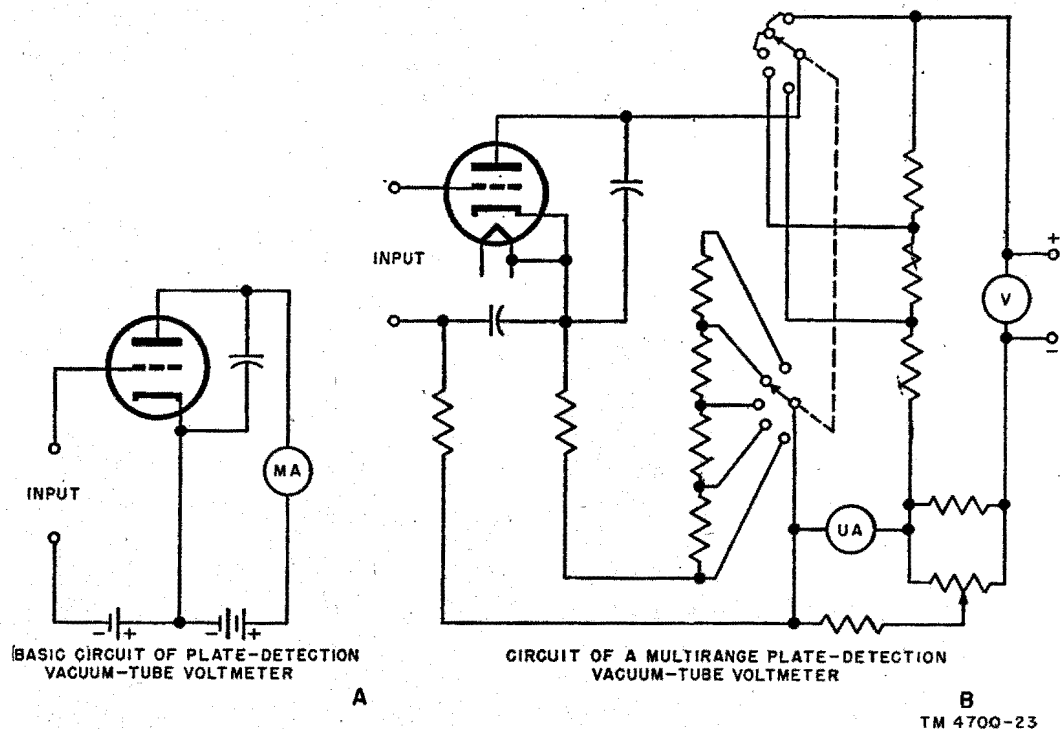


Figure 23. Vacuum-tube voltmeter circuit.

the vacuum tube is used as a rectifier, and the meter scale is calibrated in a-c volts. A of figure 23, shows the basic circuit for this type of meter. B of figure 23, shows the circuit of a multirange instrument.

28. Thermocouple Type Meter

(figs. 24, 25, 26, and 27)

Another device which makes it possible to measure a-c values with d-c meters, ordinarily of the permanent-magnet moving-coil type, is the thermocouple. If the junction of two wires of unlike material, such as iron and copper-nickel alloy, is heated with a gas flame, and the free, or cold, ends are connected to a sensitive d-c milliammeter, the meter needle deflects (A of fig. 24). The deflection is proportional to the difference between the temperature of the heated junction and the temperature of the cold ends. The thermocouple-type meter used to measure ac substitutes a resistance wire, or heater, for the gas flame (B of fig. 24). When ac passes through the resistance wire, it raises the temperature of the junction. Since the resistance of the heater is practically constant, the instrument scale can be marked in terms of current flowing in the heater circuit. The

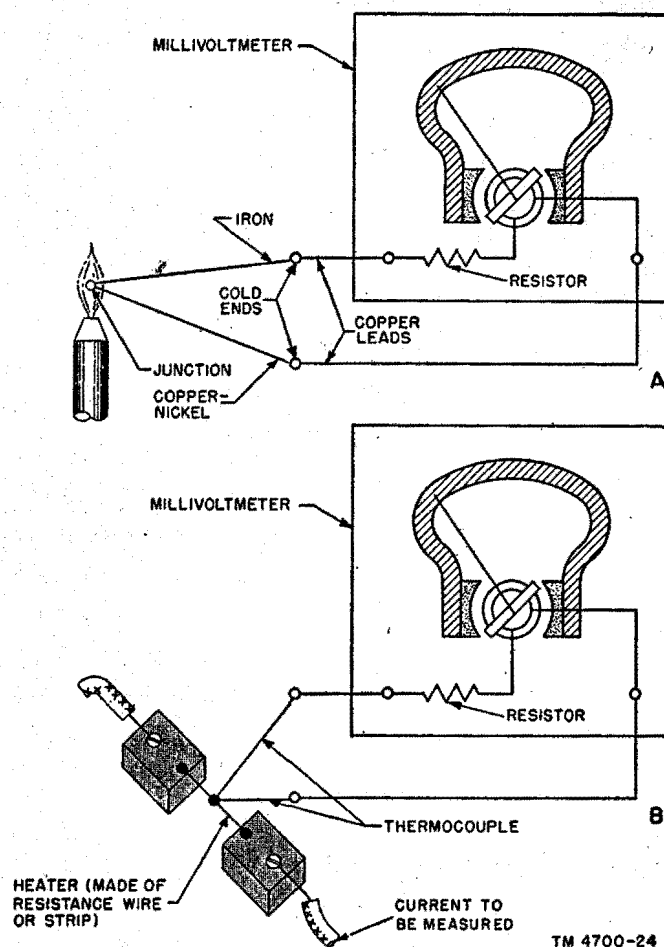


Figure 24. Principle and application of a thermocouple.

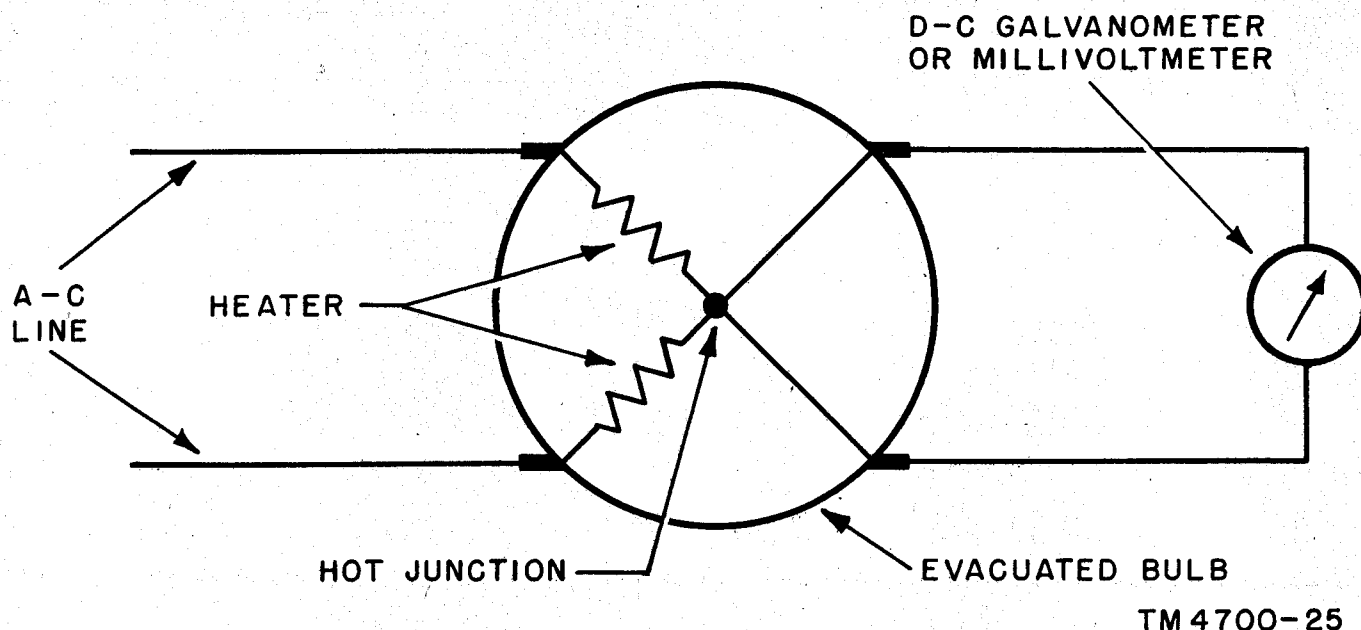


Figure 25. Vacuum thermocouple.

temperature of the heater is proportional to the square of the current flowing through it; therefore, graduations on the scale are increasingly farther apart as they approach the upper end of the scale.

a. Since the voltage from a thermocouple is proportional to the difference between the temperature of the heated junction and that of the cold junction connected to the meter, any change in the temperature of the cold junction will cause an error in the meter reading. To avoid such error, the heater generally is terminated in relatively large metal blocks, to which the thermocouple leads are joined. The leads are connected to thin copper plates, which are separated from the blocks by thin mica strips. This arrangement, which is known as cold-junction compensation, maintains the temperature of the connections at a fixed relationship to the temperature of the heater.

b. If the heater and the hot junction of the thermocouple are inclosed in an evacuated bulb, the sensitivity and reliability of the thermocouple are much improved because air currents about the hot junction and the heater are eliminated. A carbon filament may be used for the heater, and iron and alloyed metals for the junction. The vacuum thermocouple (fig. 25) of this type is very useful for the measurement of small alternating currents, usually not exceeding a few ma.

c. Millivoltmeters used with thermocouples to measure current must be more sensitive than those used with shunts, because the emf developed by a thermocouple is very small, and the internal resistance of the thermocouple is relatively low. For example, a thermocouple may have an output voltage of only 15 mv and an internal resistance of only 5 ohms.

Caution: Because of their delicate construction, thermocouple meters should be handled carefully. In thermocouple meters, the heater temperature increases as the square of the current increases. An appreciable overload, therefore, will cause the heater to burn out.

29. Frequency Meter

Frequencies of alternating currents can be measured by several methods. Generally, the frequencies used in power-supply systems are measured by either of two types of frequency meter.

a. The simplest type of frequency meter is called the vibrating-reed frequency meter (2 of fig. 28). An electromagnet (3 of fig. 28) is energized by the current in the circuit under test. The cyclic reversal of the current causes an accompanying reversal of the magnetic field around the electromagnet. A base plate (4 of fig. 28) is mounted near the electromagnet. The reversing magnetic field, with the same fre-

quency as that of the energizing current, causes mechanical vibrations of an identical frequency to be set up in the base plate. Attached to the base plate is a series of thin metal reeds (5 of fig. 28). The reeds are firmly fastened to the base plate at one end and are free at the other end. They are equal in length, but have different periods of vibration because a different weight is placed on the free end of each reed. The vibration of the base plate causes all the reeds to vibrate slightly, but the one that has a natural period nearest the frequency of the energizing current is the only one that vibrates with a large amplitude. The meter in figure 28 has 11 reeds; the lowest frequency reed is tuned to 57.5 cycles, and each succeeding reed is tuned $\frac{1}{2}$ cycle higher. This meter was designed to be used on a 60-cycle system, and the use of 11 reeds permits the reading of frequencies from 57.5 through 62.5 cycles. Variations of $\frac{1}{4}$ cycle can be estimated. In 1 of figure 28, the meter

is shown in operation, connected to a 60-cycle power supply.

b. In the second type of frequency meter, controlling and deflecting forces are supplied by current through the meter coils. Several types of meter employ this method. The meter illustrated in figure 29 shows the crossed-coil iron-vane type. If the circuits through the coils are traced, it will be seen that the amount of current flowing through the respective circuits is controlled by the reactance-resistance combinations. Inductive reactance increases and decreases, respectively, with increases and decreases in frequency. Therefore, the ratio of the controlling and deflecting forces is dependent on the frequency of the circuit, and the meter can be calibrated in terms of frequency. Note that the moving element has no control spring or zero point. When this type of instrument is not connected to a circuit, the pointer may rest anywhere on the scale.

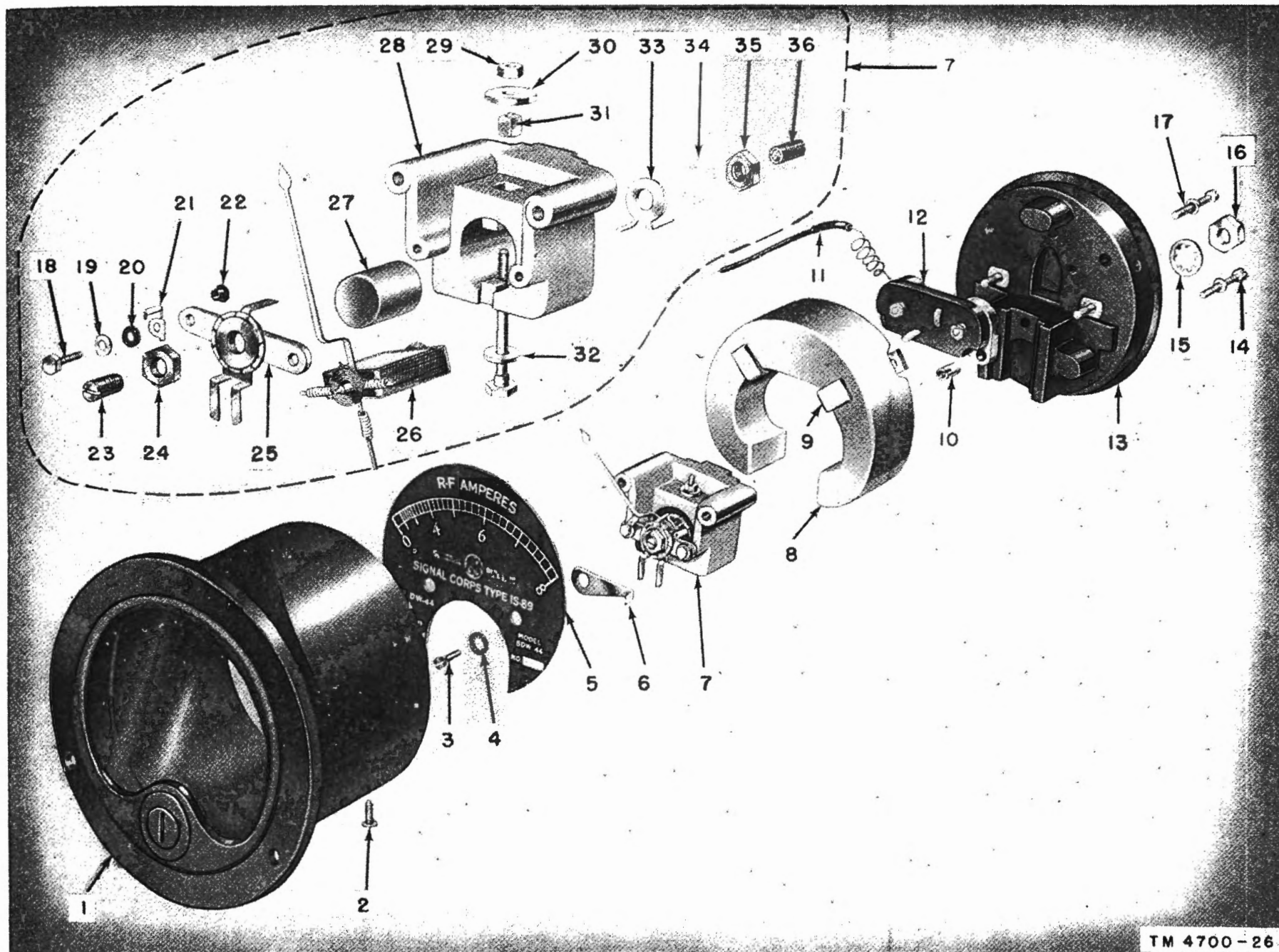


Figure 26. Disassembled radio-frequency ammeter with internal thermocouple.

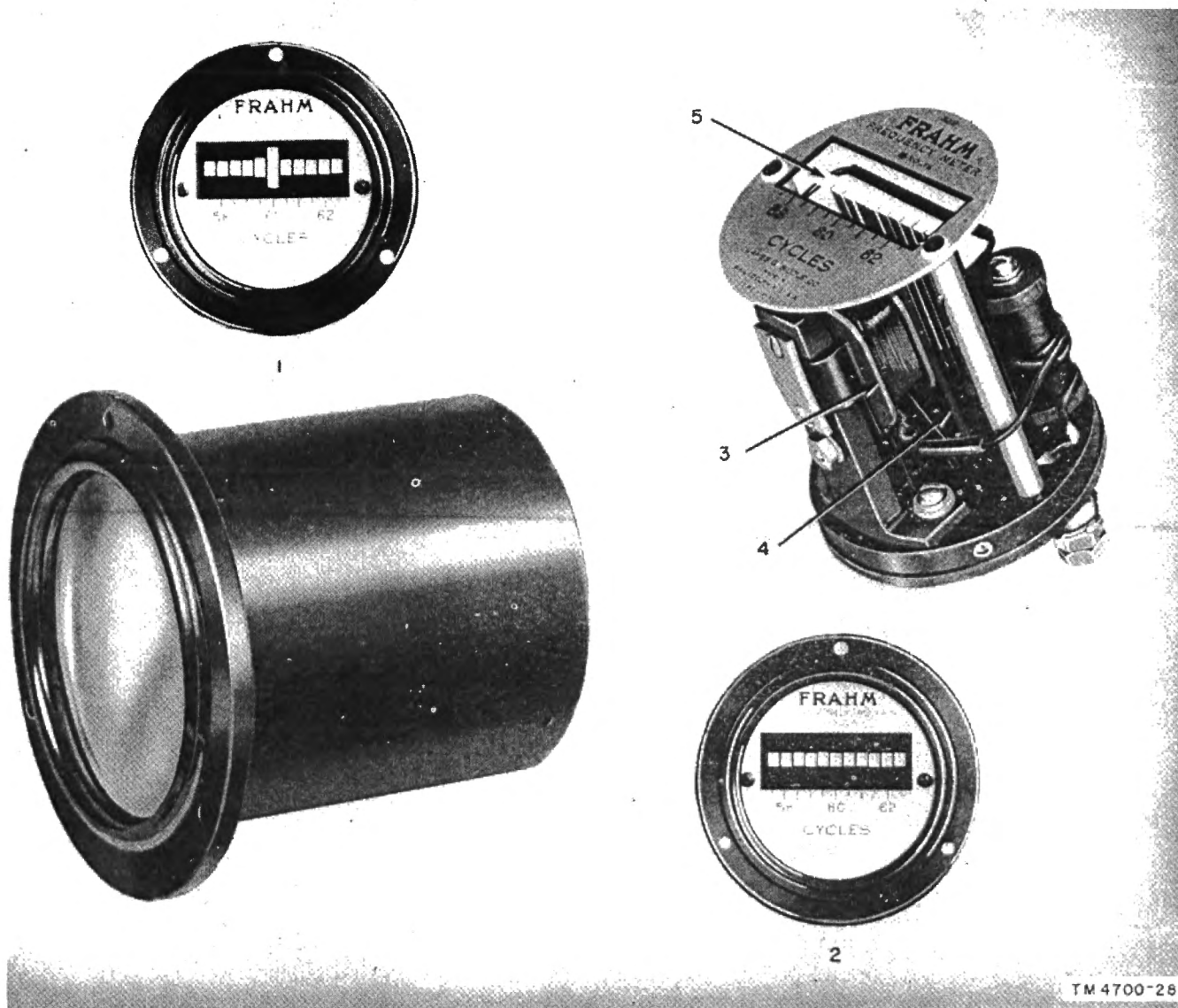
1. Cover assembly.
2. Cover screw.
- 3, 4. Scale-plate screw and lockwasher.
5. Scale plate.
6. Ground clip.
7. Element assembly.
8. Magnet.
9. Magnet clamp.
10. Thermocouple nut.
11. Series resistor.
12. Thermocouple.
13. Base assembly with terminal studs.
14. Screw for holding element to base.
- 15, 16. Terminal-stud lockwasher and nut.
17. Magnet-clamp screw.
- 18-20. Top-bridge screw and washers.
21. Pointer stop assembly.
22. Top-bridge fiber bushing.
- 23, 24. Top jewel screw and nut.
25. Top-bridge assembly.
26. Armature assembly.
27. Core.
28. Pole piece assembly.
- 29-31. Core screw hexagonal nut, washer, and square nut.
32. Core screw.
33. Lower regulator.
34. Spring washer.
- 35, 36. Bottom jewel screw and nut.

Figure 26—Continued.



1. Molded cover assembly.
2. Metal cover assembly.
3. Cover screw.
4. Scale-plate screw.
5. Scale-plate.
6. Element assembly.
7. Magnet.
8. Bottom bridge.
9. Element-bridge nut.
10. Base assembly.
- 11, 12. Element-bridge lockwasher and round nut.
- 13, 14. Terminal-stud nut and lockwasher.
15. External thermocouple (not a part of the meter).

Figure 27. Disassembled radio-frequency ammeter with external thermocouple.



1. Meter in operation.

2. Inoperative meter.

3. Electromagnet.

4. Base plate.

5. Metal reeds.

Figure 28. Vibrating-reed frequency meter.

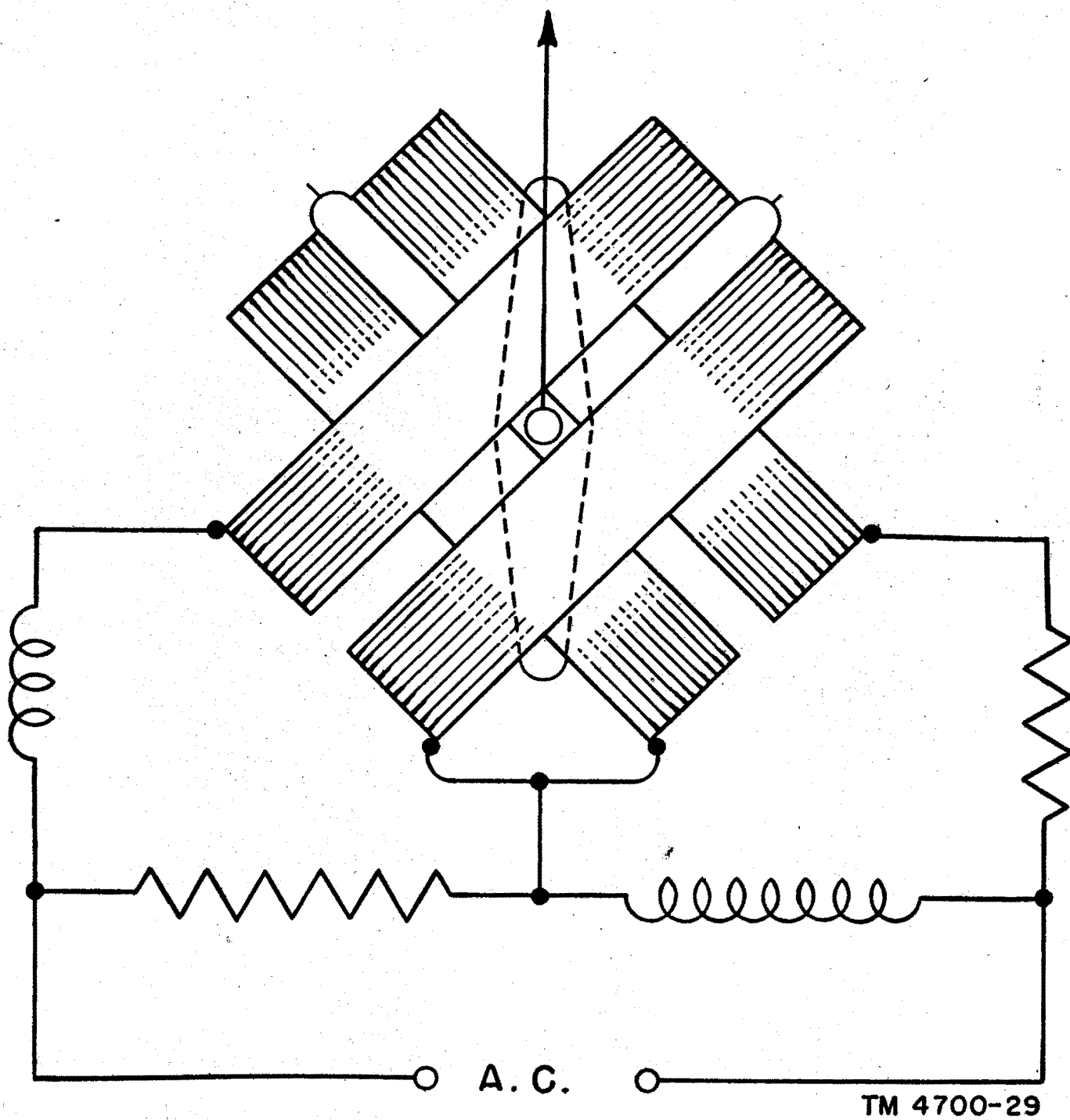


Figure 29. Crossed-coil iron-vane frequency meter, schematic diagram.

CHAPTER 3

MAINTENANCE

Section I. MAINTENANCE LEVELS

30. General

The meters used in signal equipment are delicate and expensive instruments, and their repair will be entrusted only to qualified maintenance personnel. To be qualified, the technician must have a thorough knowledge of the design and operating principles of meters and must be able to use correctly the tools and test equipment necessary for the repair and calibration of electrical measuring instruments.

31. Repair Responsibilities

a. Organizational Maintenance.

- (1) *Operator.* The operator of the equipment provided with the meters will perform only the most superficial maintenance. Such maintenance will be limited to resetting the pointer to zero when a meter is equipped with external zero adjustment and putting tape on a cracked glass or case to keep out dust and moisture.
- (2) *Unit radio repairman.* When necessary, the unit radio repairman will replace meters for which identical or standard replacements are available. In emergencies or in special local tactical situations, the repairman may open or short the circuit around a defective meter to keep vital equipment in operation. Such emergency repairs will be noted on a tag attached to the set; permanent repairs will be made at the earliest opportunity. The using-unit repairman is not authorized to make internal repairs on the meter movement.

b. Field Maintenance.

- (1) *Mobile repair shop.* Maintenance in the mobile repair shop is performed by radio repairmen attached to the repair units of division signal companies, signal battalions, and signal repair companies. Such maintenance will be limited to the replacement of meters and of external shunts, multipliers, and thermocouples in the meter circuit, but not in the meter case. In emergencies or in special local tactical situations, nonstandard meters may be substituted for defective meters to keep vital equipment in operation. All emergency repairs will be noted on a tag, and the tag will be attached to the instrument; permanent repairs will be made at the earliest opportunity. No work on the internal meter movement will be performed by the mobile repair shop.
- (2) *Fixed shop.* Fixed shop repairs are performed by signal depot companies and fixed shops in theaters of operations, in specified fixed repair shops within the continental United States, and in departmental repair shops outside the continental United States. Skilled electrical-instrument repairmen, from fixed or semifixed shops, supplied with special tools and test equipment will make complete repairs on meters, including replacement of individual parts in the meter movement, readjustment, and calibration. Meters that are beyond repair may contain critical parts in good condition that can be salvaged and used in

the repair of other meters. Salvage will not be attempted on meters that can be repaired. When a fixed shop is unable to repair a meter because of lack of parts or the absence of skilled personnel, the defective meter will be shipped to a fixed depot. Extremely precise meters, such as standard calibration meters, will be returned to a fixed depot repair shop in the United States.

c. Fixed Depot Maintenance. Fixed depot maintenance repairs are performed by departmental depot shops and other specified depot shops within the continental United States. These shops are authorized to repair meters and to restore them to their original accuracy. Standard calibration meters will be returned to the factory for any repairs which may affect their accuracy. Meters which are beyond repair will be salvaged in accordance with Army Regulations.

Section II. MAINTENANCE PROCEDURES

32. Field and Depot Maintenance Procedures

After a meter has been received at the field or depot repair shop, it should be given a mechanical and electrical inspection, as suggested below, to determine the extent of repairs required.

a. Mechanical Inspection. Check for the following:

- (1) Loose, scratched, or broken windows.
- (2) Cracked bases.
- (3) Cracked or bent cases.
- (4) Missing screws, nuts, lockwashers, or terminals.
- (5) Damaged threads on terminals.
- (6) Bent pointers.
- (7) Illegible dial markings.
- (8) Damaged or missing nameplates.
- (9) Broken zero adjuster.
- (10) Mechanical damage to internal resistors and shunts.
- (11) Internal or external evidence of rust, corrosion, or fungus growth.
- (12) External finish of the case.

b. Electrical Inspection. Place the meter in the meter-test pedestal, and check for the following:

- (1) Absence of pointer movement.
- (2) Friction in pointer movement.
- (3) Full-scale deflection of pointer.
- (4) Erratic pointer movement.
- (5) Pointer indication within tolerance limits.
- (6) Balance of movement.

c. Disassembly for Major Repairs to Internal Mechanism. To disassemble any meter, proceed as follows:

- (1) Remove the movement from the case.
- (2) Remove the dial screws and slide the dial from under the pointer. Be careful not to bend the pointer.
- (3) Remove the movement and magnet from the base.
- (4) Unsolder the hairsprings and all other soldered connections.
- (5) Remove the screws from the top and bottom bridge.
- (6) Remove the top bridge and lift out the moving-element coil.
- (7) Place a keeper over the air gap of the permanent magnet.
- (8) Clean and dry each part thoroughly.

d. Diagnosis of Trouble. Meter troubles fall into two general classes characterized, respectively, by failure of the instrument to indicate and by failure to indicate correctly. The following tables list a variety of mechanical and electrical troubles associated with these two types of trouble.

(1) *Instrument fails to indicate.*

Possible trouble	
Mechanical	Electrical
Pointer sticking.	Open coils.
Element dislodged from jewels.	Open resistance unit.
Pivots too tight in jewels.	Loose connections.
Damping vane sticking.	No external circuit.
Damping disk lying on magnet.	Shorted coils.
Broken pivots.	Opposite polarities in divided stationary coils.
Coils sticking because of foreign matter between them.	Shorted transformer.

Possible trouble	
Mechanical	Electrical
Coils warped. Loose wires. Coil cement on hairsprings or in air gap. Cross arms caught on adjacent parts.	Open in transformer winding.

(2) *Instrument indicates incorrectly.*

Possible trouble	
Mechanical	Electrical
Static or rolling friction. Pointer sticks in upscale position. Movement off-balance. Spring convolutions touching. Loose or bent pointer. Zero shifts. Annealed or set springs. Loose spring connections. Loose pivots. Loose jewels. Pointer not operating full-scale. Too much or not enough end play. Dial or element shift. Coils rubbing. Damping vane rubbing. Tail weight hitting zero-adjustment pin. Pointer touching dial or glass. Pointer shaft touching coil. Damping disk touching magnet. Element shaft touching damping-chamber cover.	Poor or incorrect connections. Grounds. Partially shorted cells. Open shunt. Magnetized metal cases or steel panel mountings. Incorrect frequency. Distorted coils. Field effects between elements.

33. Mechanical and Electrical Repairs

a. Windows. Reseal loose windows. Where the original compound has become dry, remove it by scraping with a knife or other suitable tool before applying new seal. Be careful when removing bezel rings. Replace windows which are broken or scratched to the extent that visi-

bility is impaired. If the damaged window is in a sealed meter, proceed as follows:

- (1) Ascertain the type of seal used (fused, crimped, or screwed).
- (2) If the meter is sealed by the fusion method, remove the window by using an induction soldering iron; replace the window, and seal it by using the same soldering unit.
- (3) If the meter is sealed by a crimping ring, remove the ring by using a pair of pliers. Note the position of the gasket. Install the new window and a new gasket, if one is available, and use a new crimping ring to seal the meter.
- (4) If the meter is sealed by screws, unscrew them, and remove the top of the meter, the gasket, and the damaged window. Install a new window; a new gasket, if one is available; and the screws.

b. Cases and Bases. Repair small cracks in bakelite or composition cases and bases by sealing the cracks with cement and allowing it to dry. Discard cases and bases that are cracked beyond repair. Salvage other parts of the meter for future use. When meters have good cases and bases, but are otherwise beyond economical repair, salvage the cases and bases for future use. Straighten bent metal cases by using suitable mandrels.

c. Hardware and Terminals.

- (1) *Hardware.* Replace all missing hardware. When repacked for shipment, the instrument should be complete with all necessary terminal nuts, washers, and mounting hardware.
- (2) *Terminals.* Terminals with damaged threads should be rethreaded. Be sure to use the proper die, and do not change the thread size. Replace terminals that are damaged beyond repair.

d. Pointers, Dials, and Zero Adjusters.

- (1) *Pointers and dials.* Straighten bent pointers. If the finish becomes chipped or marred, refinish the pointer with the proper color lacquer. Rebalance the movement after straightening or refinishing the pointer. Replace or re-

touch illegible dials. If a new dial is not available, a suitable replacement may be fabricated by a photographic process. Photograph the dial of an identical meter, and make a print of the identical size from the negative. Then cut out the scale and cement it on the old dial. Pointers and dials treated with radioactive luminous compound should not be repainted in Signal Corps shops *unless* the provisions of TB Med No. 232 can be met satisfactorily, and sufficiently skilled personnel and adequate instructions are available to accomplish the work.

- (2) *Zero adjusters.* Replace broken zero adjusters. *Be careful to avoid cracking the glass.*

e. Cleaning and Refinishing. Clean the instruments thoroughly to remove any dust, dirt, corrosion, or fungus growth. Use clean, lint-free cloths and clean alcohol, solvent, or benzine. Cleaning fluid should be kept clean and changed frequently. Soft brushes, such as those used by jewelers, will facilitate the removal of foreign matter from parts and assemblies.

Caution: Do not use steel wool to clean meter parts; it is impossible to prevent particles of the wool from adhering to the magnet.

f. Balance. To assure uniform calibration over the entire scale, meter movements must be balanced. The pointer of a properly balanced meter will indicate zero, regardless of the position of the meter. Minor corrections are made in the field by means of the zero adjuster. However, adjustment of the zero adjuster does not correct an unbalanced condition in the meter movement. To check the balance of a meter movement, proceed as follows:

- (1) Lay the meter flat on its back, and note the position of the pointer with relation to the zero calibration mark. If the pointer does not rest over the zero mark, operate the zero adjuster to correct the pointer to zero.
- (2) Place the meter in an upright position and turn it until the pointer is vertical. If the pointer is not at zero, the horizontal balance must be adjusted (fig. 30).

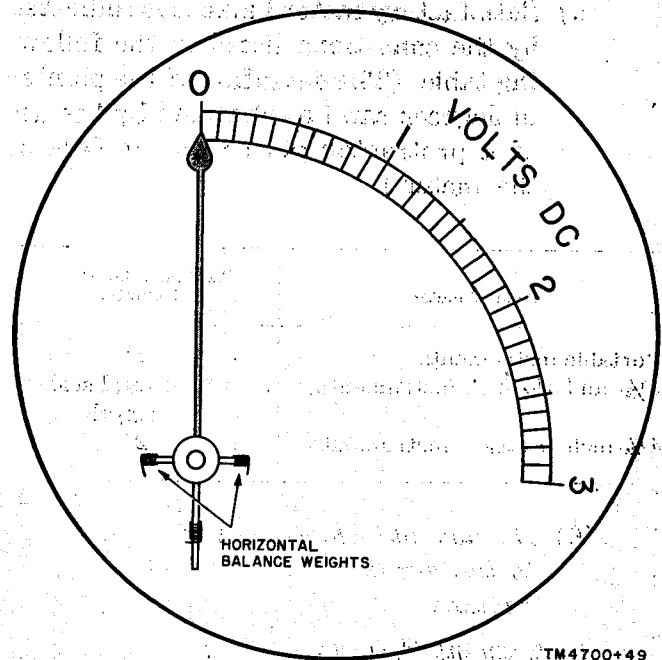


Figure 30. Horizontal balance weights.

- (3) To check the tail weight, continue to hold the meter in an upright position and turn it clockwise or counterclockwise until the pointer is horizontal. If the pointer will not come to zero, the tail weight (fig. 31) requires adjustment.
- (4) For proper adjustment of the horizontal balance weights and the tail weight, refer to paragraph 34a.

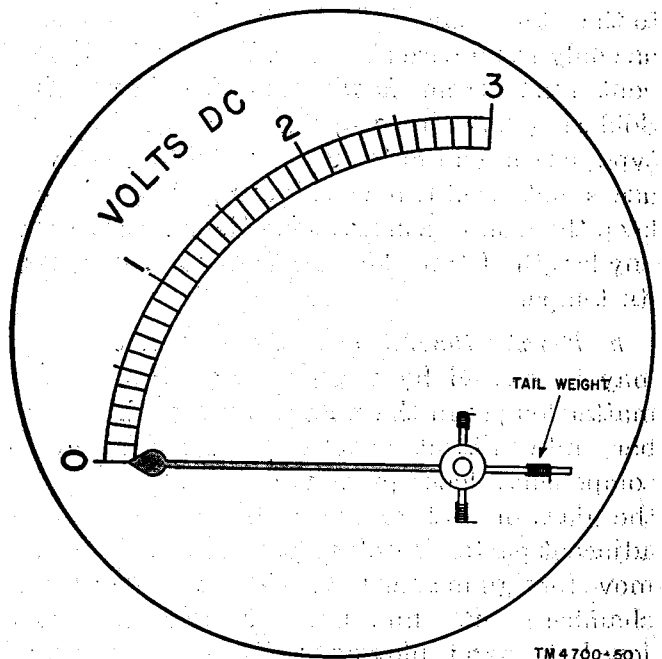


Figure 31. Tail weight.

- (5) Satisfactory meter balance is indicated by the conditions listed in the following table. (The deviation of the pointer in degrees can be estimated by the use of a protractor placed on the face of the meter.)

Type of meter	Maximum deviation of pointer
Portable instruments. 2½- and 3½-inch instruments.	1° 2% of total scale length
4½-inch or larger instruments.	2°

- (6) *Do not add shellac, lacquer, or paint to the weights or cross arms to effect balance.*

g. Instrument Fails to Indicate. This condition may result from several causes, such as lack of current or voltage input to the meter, open meter coil or series resistor, or defective rectifier or thermocouple. First, make sure that current is applied from the external source to the meter terminals. Use Meter Test Set TS-682/GSM-1 to check the meter coils and connecting leads for continuity. Replace open movements unless the open can be located and repaired readily. If the movement check is satisfactory, and the meter still fails to indicate, check the other components of the circuit. Make sure that the hairsprings are soldered properly to their terminals. When soldering hairsprings, use only rosin-core solder and be careful to prevent rosin from flowing on the hairspring. Soldering flux, if used, should be of the paste type; use only minute quantities of flux. Always use a hot, well-tinned soldering iron. Do not keep the iron in contact with the hairspring for any length of time, because the heat will change its temper.

h. Erratic Pointer Movement. This condition may be caused by a poor connection, foreign matter lodged in the air gap or damping chamber, intermittent shorts or opens in circuit components, loose pivot pads, pointer touching the glass or dial, or balance arms catching on adjacent parts. Resolder poor connections. Remove foreign matter from air gaps and damping chambers with fine brushes, tweezers, or a jeweler's hand blowgun. Do not use strong blasts of compressed air, which may damage

the hairsprings. Replace circuit components that have intermittent opens or shorts, if they cannot be repaired. If loose pivot pads are recemented, work carefully to insure proper alignment. Fabricate series resistors, adjusting coils, and small shunts of the wire-wound type if exact duplicate replacements are not available.

i. Excessive Friction in Moving Mechanism. Check for friction by using a working standard to vary the reading of the meter over its entire scale. Do this slowly, without vibrating the meter under test. Friction error in excess of 2 percent of the total scale length indicates internal faults which must be located and corrected. Although the most probable causes of friction are blunt pivots and cracked jewels, check the meter, before it is completely disassembled, for other causes, such as: a static charge on the glass, which can be dissipated by breathing on it; the presence of foreign matter in the air gap or damping chamber; and improper jewel-clearance adjustment. If correcting these conditions does not remove the friction, disassemble the meter and examine the pivots and jewels.

34. Adjustment Procedures

a. Balance Weights.

- (1) *General.* If the balance of a moving element must be adjusted (par. 33f), make the adjustment according to the information given in (2), (3) and (4) below. If the pointer is resting at zero when the meter is in its normal position, but moves off zero as the meter is turned clockwise through 360°, the moving element is out of balance. Check the position of the pointer at each ¼ turn for maximum deviation, and balance the moving element by adjusting the appropriate weight until the pointer is restored to the zero position (fig. 32).
- (2) *Split-thread balance weight.* Since the split end of a split-thread balance weight will cut its own thread on the shaft if not properly adjusted, compress it until it has an inside-thread diameter minutely smaller than the

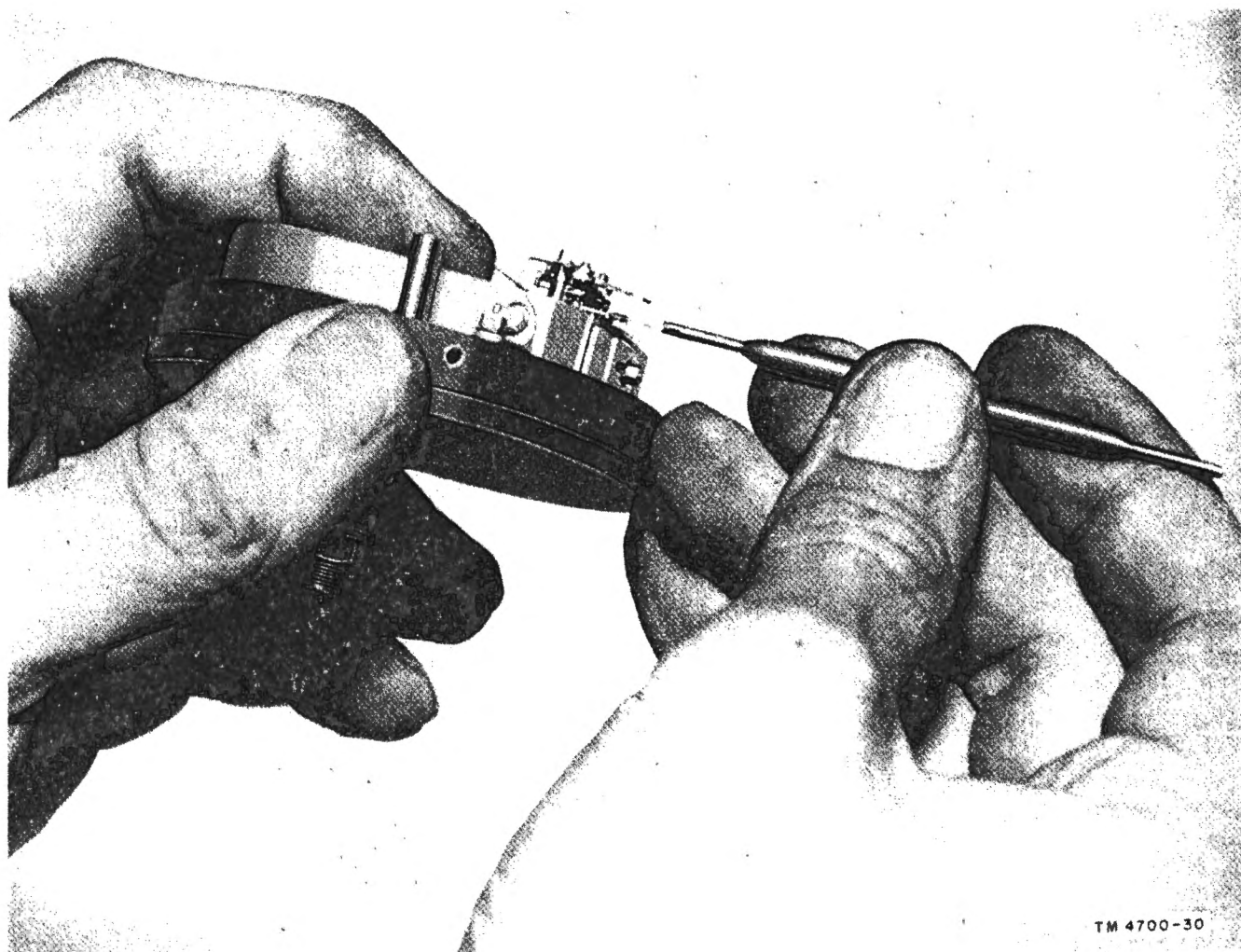


Figure 32. Correct method of adjusting balance weights.

thread diameter of the shaft. When assembled, a properly adjusted spring weight should grip the shaft just sufficiently to eliminate shifting and to avoid cutting its own thread (fig. 33).

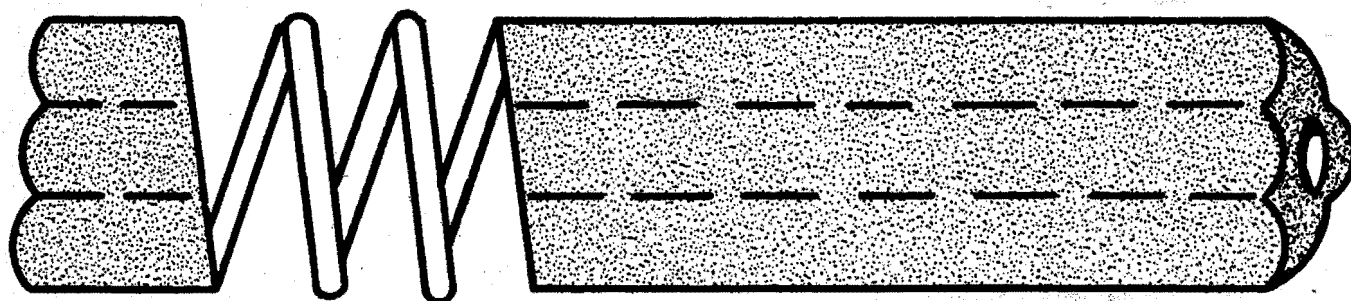
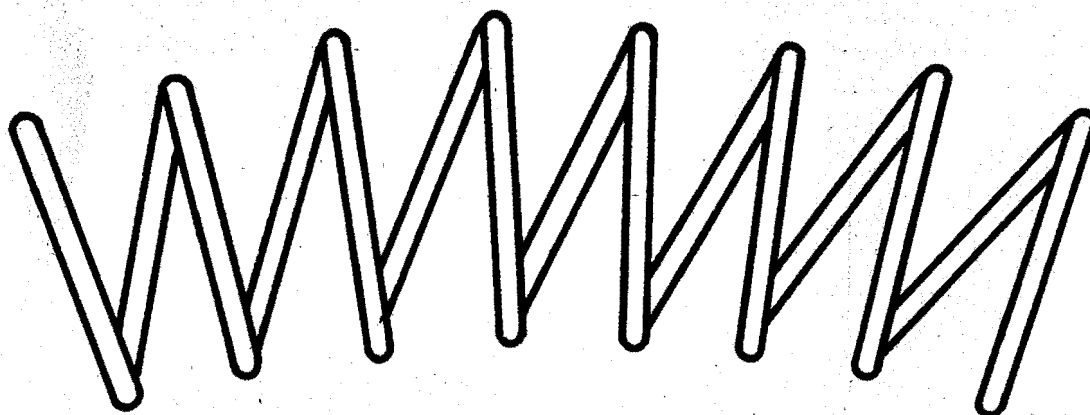
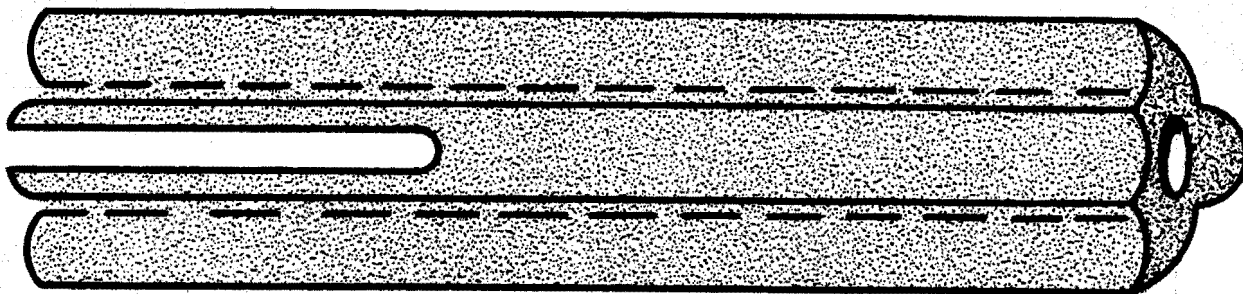
- (3) *Wire-wound balance weight.* The wire-wound type of balance weight (fig. 33) is most widely used in small instruments. It is made of bronze wire wound helically on a slightly curved arbor to give it greater gripping strength. To avoid damaging this type of weight when making adjustments, grip the entire length with a pair of flat-surfaced tweezers, and turn the weight in the desired direction. *Never pull or push this type of weight.* Pulling or pushing will change the distance between turns and alter the calibration of the meter.

- (4) *Locknut balance weight.* The locknut balance weight (fig. 31) has three or four threads near the end of the nut, which are usually smaller than the thread on the shaft. Never force this type of weight. Forcing will damage the threads and cause the weights to shift under vibration. The locknut balance weight has a hexagonal end. Use a balance wrench of the correct size when making adjustments.

Caution: Never cement or solder weights to the shaft.

b. *Zero Adjustment.*

- (1) After the balance weights have been adjusted, the pointer can be set at zero either by shifting the lower spring adjuster or, in the case of a two-piece adjuster, by moving the slip-



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Figure 33. Three types of modern balance weight; split-thread type (top), wire-wound type (center), and lock nut type (bottom).

- spring collet on the shaft to shift the top, or spring-contact, side.
- (2) To shift the lower spring adjuster, grasp the end, where the spring is soldered, with a pair of tweezers and move the arm either upscale or downscale until the pointer rests at zero.

- (3) To shift the top, or spring-contact, side of a two-piece adjuster, loosen the nut that holds the spring and the lower adjustment arm tight. It may be necessary to use a small wrench. While holding the upper spring holder in the center position, move the lower spring

holder with a pair of tweezers until the pointer rests at zero. *Be careful not to bend the hairsprings.* If the pointer moves from its zero position after the movement has been inserted in the case, the necessary correction can be made by turning the external adjustment screw.

c. Pivots.

- (1) *General.* Meter pivots, which are made of hardened steel or some other very hard material, are mounted either on the outside or on the inside of the moving coil. They are capable of withstanding considerable wear and tear. The pivots are shaped to fit into jeweled bearings with a minimum of end and side play.
- (2) *Rough or flattened pivots.* Rough or flattened pivots are a serious source of trouble in meters. In the D'Arsonval type movement, the pivots are removable. To polish a pivot, proceed as follows: Place the moving element, including the coil, spring, pointer, and pivots, over a formed bakelite or wooden mandrel (fig. 34) shaped to fit the coil. Insert the end of the pivot in a lathe. *Be sure to use a chuck of the proper size.* Slowly turn the lathe by hand until the pivot is held tightly. Continue to turn the lathe by hand, and pull straight back on the formed mandrel very gently. The pivot will pull out of the pivot base. Remove the pivot from the chuck with a pair of tweezers (fig. 35), insert the reverse end, and retighten the chuck. Using either an India or Arkansas polishing stone (fig. 36), slowly turn the lathe so that the pivot rotates evenly, and proceed to polish the end of the pivot. Use jeweler's rouge to complete the polishing. To replace the pivot after it is polished, reverse the procedure for removing it. *Be careful not to bend the damping coil or to injure the springs.*

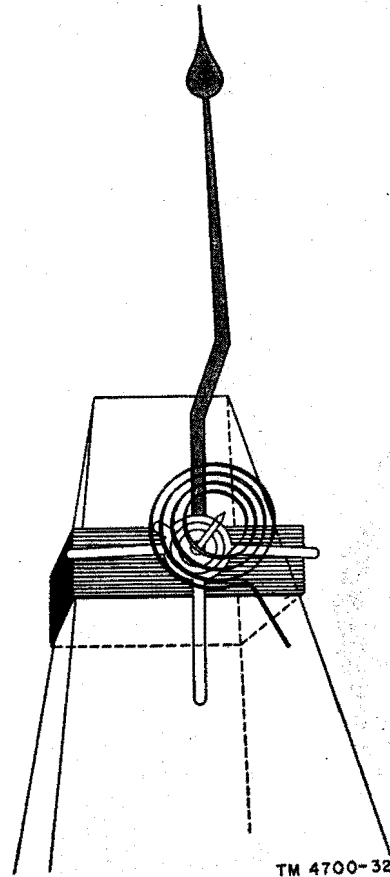


Figure 34. Movement mounted on formed mandrel.

Caution: Never hold the polisher stationary. Keep it moving back and forth under the pivot.

d. End-Play Adjustment. Proper end-play adjustment (fig. 37) is essential to the accurate functioning of a meter. If the moving element is set too tightly in the jewels, sluggish action will result, and the pivots will become flattened.

- (1) In most meters, the pivots are mounted externally on the moving coil (A of fig. 38). To test end play in this type of movement, grasp the base of the pointer very gently with a pair of tweezers, and move the element up and down. If there is too much end play, tighten the jewel screws with a jeweler's screw driver until proper end play is obtained.
- (2) In the internal-pivot type of moving element (B of fig. 38), the pivots are mounted on the inside of the top and

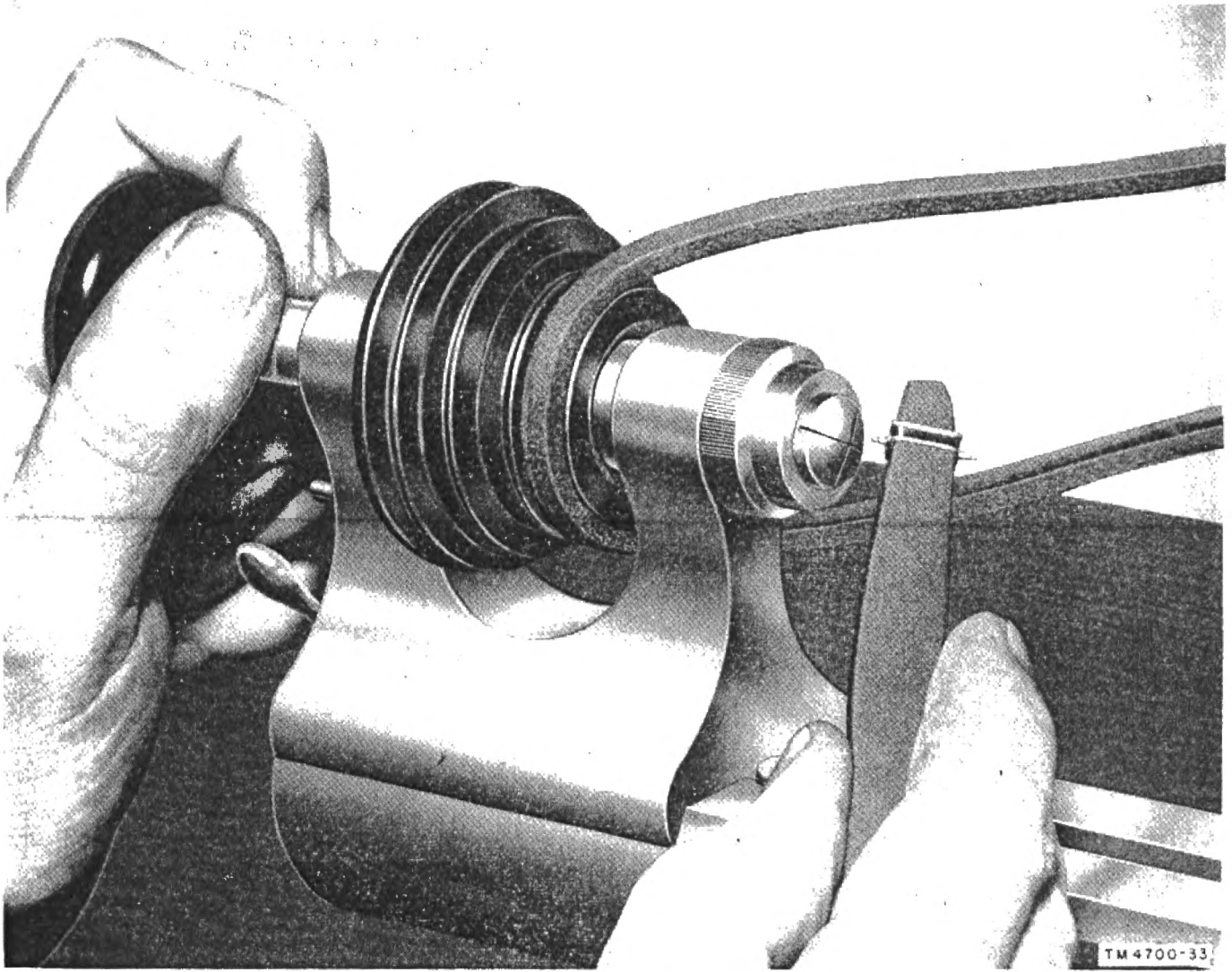


Figure 35. Proper method of removing pivot.

bottom of the rectangular aluminum shell. End play is adjusted by means of a compression spring within the core. The compression spring does not support the upper jewel which is rigidly mounted in the top of the frame and core assembly. It does, however, maintain pressure on the lower jewel sleeve which can be adjusted by tightening or loosening the adjusting set screw.

e. Jewels (fig. 39). The V-shaped jewels used in meters are made of tough, highly polished, low-friction glass or sapphire mounted rigidly in jewel sleeves. Jewels must be given the same careful attention as pivots. To check for a cracked or broken jewel, remove any encrusted dirt with a needle and inspect the jewel with a

jeweler's eye loupe. Replace cracked or broken jewels with new ones.

Caution: Never oil the jewels.

f. Hairsprings.

- (1) *General.* Meter hairsprings are rolled to the correct proportions and aged to relieve mechanical stresses and to minimize hysteresis. They retain their stability with age, with variations in temperature, and under load, but not if they are abused during servicing. In most cases, the inner end of the hairspring is soldered to a collet that is attached firmly to the shaft of the moving element. The outer end usually is soldered to the upper tip of the zero regulator.

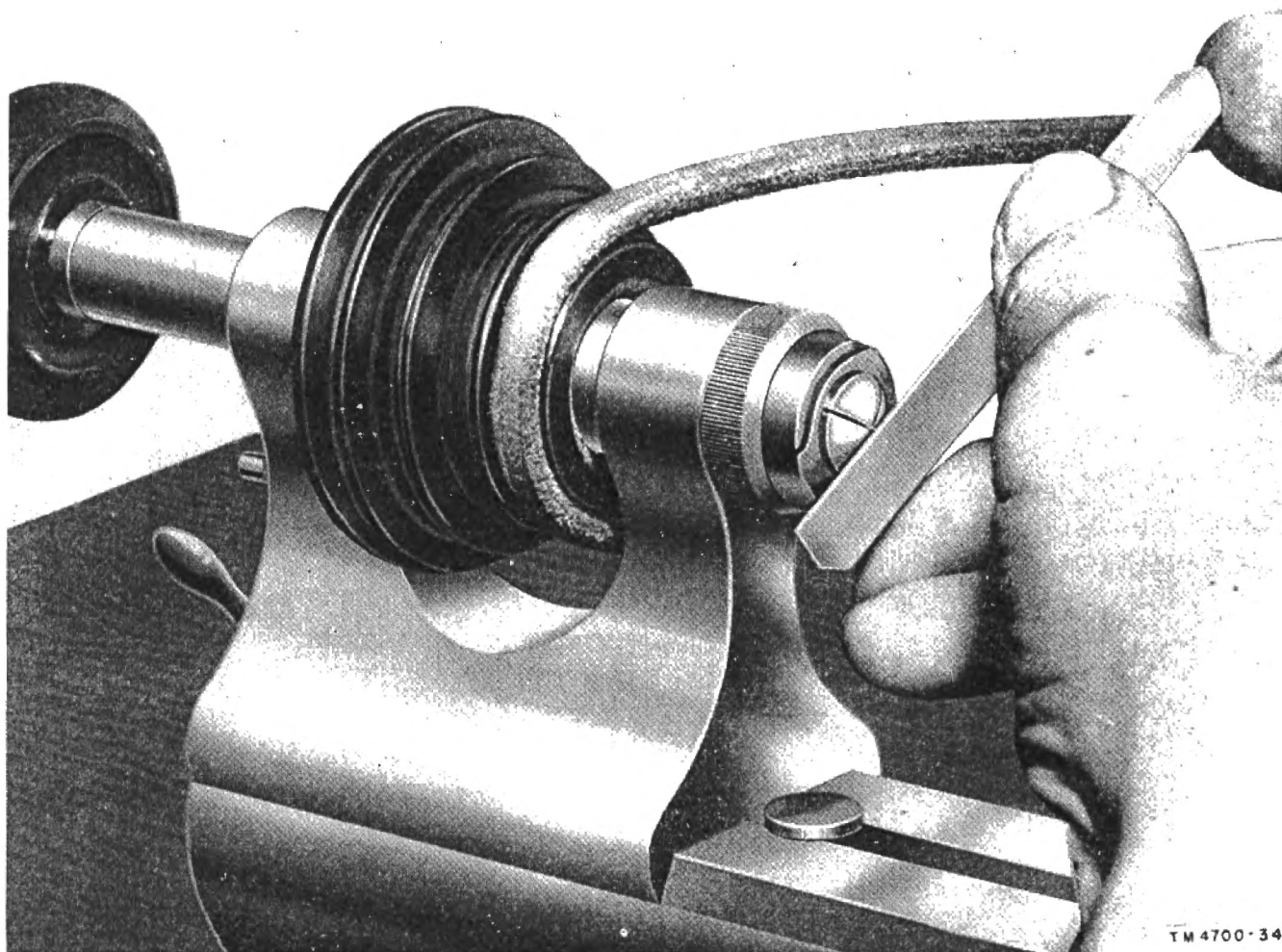


Figure 36. Correct method of holding the polishing stone.

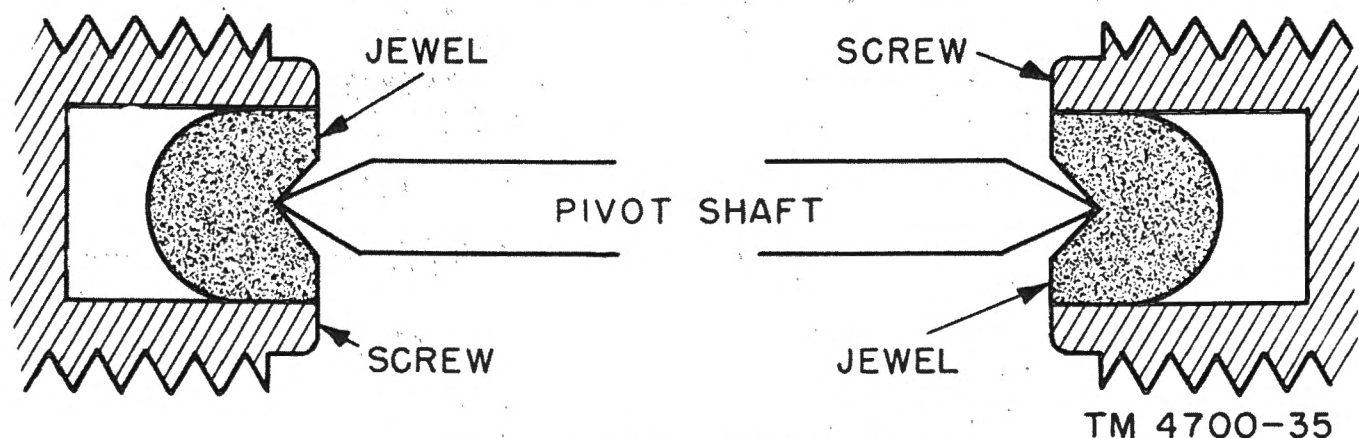


Figure 37. Correct position of pivots in jewels.

(2) *Resoldering hairspring.* To resolder hairspring in position, proceed as follows: First, clean the surfaces thoroughly. Use a very small amount of nonacid, noncorrosive, soldering flux, and be sure that the iron is hot enough

that the solder will flow freely. Do not hold the iron in contact with the hairspring too long; too much heat will cause local annealing and consequent uneven elasticity of the spring. After a spring has been soldered, wash

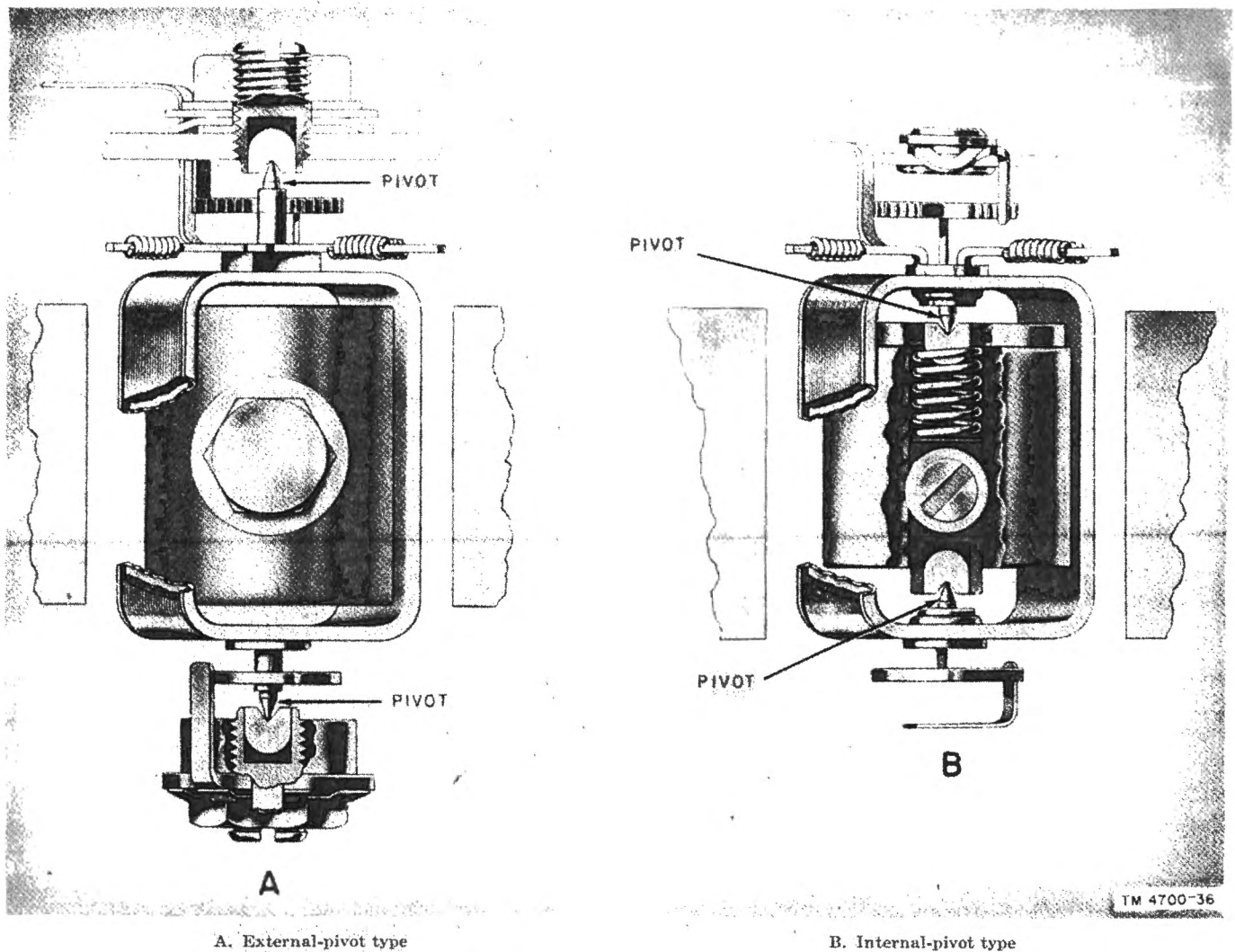


Figure 38. Two types of pivot arrangement.

it thoroughly in a good cleaning solution to remove any remaining soldering flux or grease that might cause the convolutions of the spring to stick together. When soldering a spring, be careful not to put any strain on the coils; keep the spring relaxed.

- (3) *Straightening or bending hairspring.* When a new hairspring must be straightened or bent, make the radius of the bends as large as possible (fig. 40). Incorrect bending and shaping of the hairspring cause uneven convolutions which will make contact when the spring is under strain. After adjusting a hairspring, run the pointer upscale and note whether there is any contact between convolutions of the springs. When making this test, be

sure that the spring does not touch any adjacent parts.

35. Calibration of D'Arsonval, Iron-Vane, and Electrodynamometer Type Meters

a. Calibration of D'Arsonval Type Meters. When the necessary repairs have been made and the parts are clean and ready for assembly, proceed as follows:

- (1) Magnetize the permanent magnet (par. 45).
- (2) Resolder all connections, clean the wires leading from internal connections, and apply a small amount of soldering flux to the ends. Solder the hairsprings in the *no-torque* position.
- (3) In meters with internal resistance

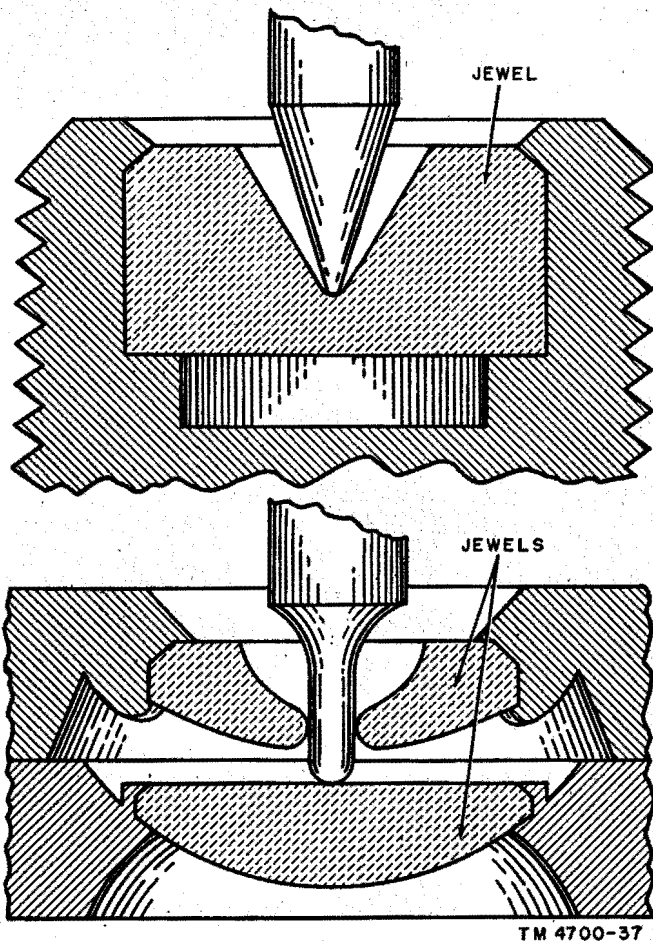


Figure 39. Two types of jewel.

SPACING SHOULD BE
AS EVEN AS POSSIBLE

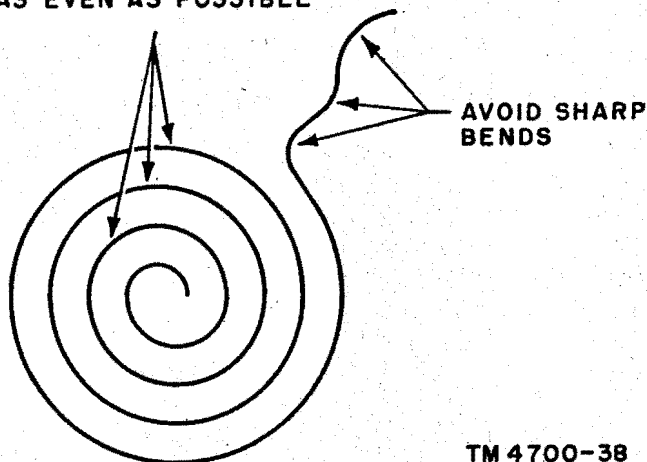


Figure 40. Correct method of shaping hairsprings.

spools, examine the resistance windings, and use an ohmmeter to test them for opens or shorts. If it is necessary to replace a resistor, be sure that the correct value is used. Measure the resistor on a Wheatstone bridge

and make necessary corrections before it is installed.

- (4) To calibrate the meter with Meter Test Equipment AN/GSM-1B (TM 11-2535A) mount the meter movement in the meter pedestal and make the proper connections to the test equipment. When checking the reading on the standard meter against that of the meter under calibration, be sure to take direct front-view readings to avoid parallax. If the reading of the repaired movement is too high, demagnetize the permanent magnet (par. 45) by holding the demagnetizing coil in a position perpendicular to the movement so that it will not be demagnetized too much. When the meter reading corresponds to that of the standard, release the switch on the demagnetizer and continue with the test. Check for friction on the pointer by running the pointer slowly across the scale. If friction is present, recheck for rough or flattened pivots, dirt in the air gap, and rubbing of moving parts.

- (5) The calibration of the meter must be accurate to within plus or minus 2 percent of full-scale deflection. If the magnet charger is used properly, the magnet should be saturated and then demagnetized to within tolerance limits. The series resistors should never be adjusted more than is necessary to bring the meter reading within plus or minus 2 percent of full-scale deflection after demagnetization. When the meter has been calibrated, check the accuracy at cardinal divisions that approximate one-fourth, one-half, three-fourths, and full-scale deflection.

b. Calibration of Iron-Vane Type Meters.

- (1) *General.* Iron-vane type (a-c) meters can be calibrated either by changing the resistance of the shunt across the meter terminals or by changing the position of the vanes.
- (2) *Changing position of vanes.* There are several methods of changing the posi-

tion of a vane for calibration purposes. In all cases, the object is to change the distance between vanes in the no-load position so that the relative position of the vanes will be altered when the vanes are magnetized.

- (a) One method of changing the vane positions is to shift the complete element by an amount sufficient to bring the pointer to zero. Since the pointer and the moving vane are on the same shaft, this adjustment changes the position of the moving vane with relation to the stationary vane.
 - (b) If the stationary vane is mounted on a movable bracket, make the adjustment by moving the vane in or out until the full-scale indication of the instrument under test is the same as that of the standard against which the check is being made.
 - (c) If the stationary vane is a wire rod mounted on a cam-shaped screw, change the position of the vane by turning the screw. When the screw is external, make the adjustment without removing the instrument from the case.
- (3) *Changing shunt resistance.* In the shunt method of calibration, a resistance unit is connected across the meter terminals. To withstand temperature changes, the shunt should be made of manganin wire. Because the electrical forces of the instrument depend on the current in the coils, and because the shunt absorbs a portion of the current to be measured, the shunt resistance controls the current that flows in the coils. The shunt may be in the form of a resistance spool, resistance card, or flat resistance strip. If wire is added to the shunt, the resistance of the shunt increases, the current that flows through the coil increases, and a higher reading is obtained. If wire is removed from the shunt, the resistance of the shunt is reduced and a lower reading is obtained. The resistance of a strip shunt can be increased by removing some of the strip material

with a file. The resistance can be decreased temporarily by depositing melted solder on the strip. However, if the resistance is too high, the strip shunt should be replaced.

c. Calibration of Electrodynamometer Type Meters. Place the meter to be tested in a circuit (fig. 41). Take a reading when the current is flowing in the forward direction and another reading when the current is flowing in the reverse direction. Then calculate the median of the two readings; the result is the calibrated reading. To calibrate this type of instrument: shift the pointer, adjust the resistance in the stationary coil circuit, and balance the element. Use a voltage box to reduce the voltage to 1.5 volts. To test an electrodynamometer-type ammeter, place the instrument to be tested in series with a standard shunt. The calibration can be made only with dc.

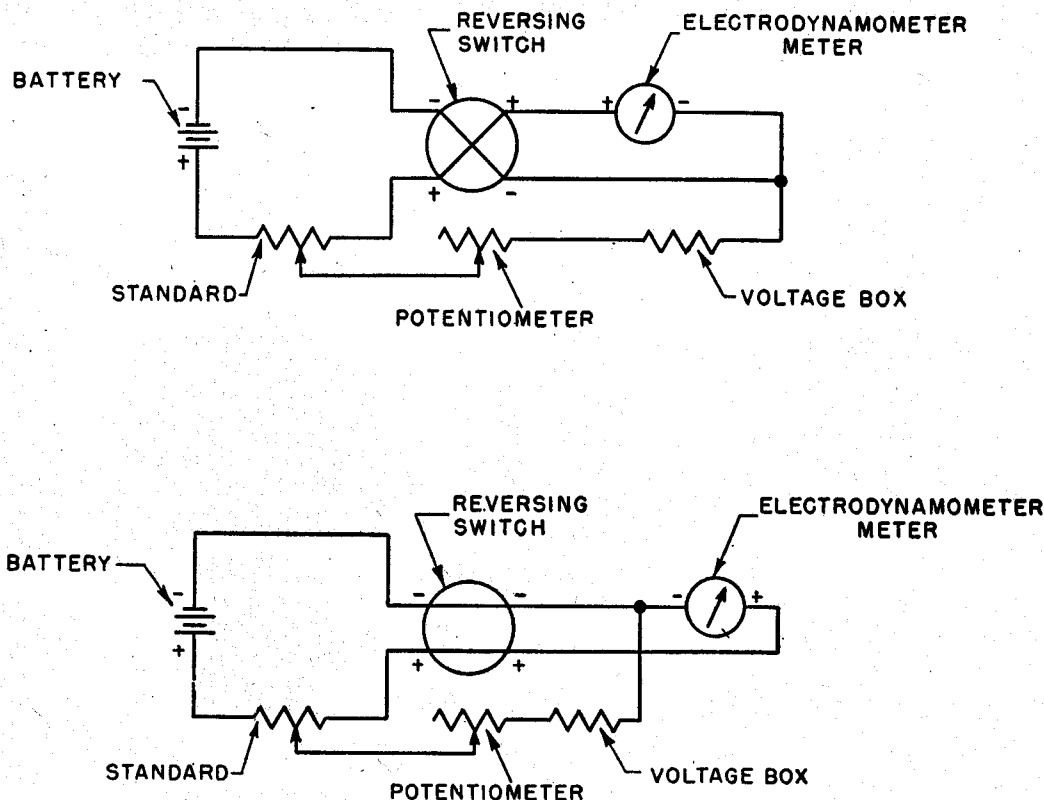
36. Calibration Procedures for Rectifier and Thermocouple Type Instruments and Decibel Meters

a. Calibration Procedure for Rectifier Type Meters.

- (1) Check the balance of the movement (par. 34a).
- (2) Set the pointer at zero with the mechanical zero adjuster.
- (3) Connect the meter to the working standard (par. 35).
- (4) Select the proper range of the standard meter, and adjust the reading until it equals full-scale value of the meter being calibrated.

Note. Proper 60-cycle voltage should be applied to the rectifier. If the rectifier is internal, apply the voltage to the meter terminals. If the rectifier is external, apply the voltage to the appropriate terminals of the rectifier and connect the rectifier to the meter.

- (5) Compare the reading of the repaired meter with that of the working standard. Normally, the repaired instrument will read high because of the saturation of the magnet. Readings must agree within specified tolerances.
- (6) Calibrate the meter by aging the magnet as follows:
 - (a) Plug the demagnetizing coil into the proper a-c outlet.



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Figure 41. Calibration diagram for electrodyname meter type meters.

- (b) Hold the coil approximately 1 foot from the repaired instrument and depress the switch in the handle. The resultant alternating magnetic field set up around the coil weakens, or ages, the meter magnet and thereby reduces the reading on the meter.
- (c) To vary the strength of the demagnetizing effect, control the voltage applied to the demagnetizing coil by using a variac, or vary the distance between the demagnetizing coil and the meter. The closer the coil is to the meter, the greater is the demagnetizing effect.
- (d) Continue to demagnetize the coil until the reading on the meter under calibration equals the reading of the working standard meter, within the specified allowable tolerance.

Caution: Do not bring the demagnetizing coil closer than 3 feet to the working standard meter.

- (e) Minor calibration adjustments not in excess of 5 percent of the full-

scale reading of the meter may be made by adjusting the resistance in series with the meter movement.

- (f) When extreme accuracy is required, or when the accuracy after demagnetizing is not within allowable tolerances, minor calibration adjustments may be made, in some meters, by varying the position of the magnetic shunt located near the pole pieces and by increasing or decreasing the resistance of the internal series resistor.

Caution: Do not change the value of the internal resistor more than is absolutely necessary to obtain the specified accuracy at full-scale reading.

b. Calibration Procedure for Thermocouple-Type Meters.

- (1) Check the balance of the movement (par. 34a).
- (2) Set the pointer at zero with the mechanical zero adjuster.
- (3) Connect the meter to the working standard (par. 35).

- (4) Select the proper range of the working standard and adjust the reading until it equals the full-scale value of the meter being calibrated.

Note. Use 60-cycle ac to calibrate thermocouple meters. If the thermocouple is internal, apply the voltage to the meter terminals. If the thermocouple is external, apply the voltage to the appropriate terminals of the thermocouple.

- (5) Compare the reading of the meter under test with that of the working standard meter. Normally, the meter will read high because of the saturation of the magnet. Readings must agree within specified tolerances.
- (6) Calibrate the meter by aging the magnet (par. 36a(6)).

Note. The meter may be calibrated without the external thermocouple by applying d-c voltage to terminals or connections of the meter that normally are connected to the external thermocouple. Do not use this method when the d-c voltage required to produce full-scale deflection is unknown. Meters calibrated by this method should be given a final check for accuracy when used with the thermocouple normally associated with the meter.

- (7) Replace defective thermocouples. Fabrication of thermocouples is not recommended, except in cases of emergency. Exact duplicates are contained in Meter Repair Parts Kit MK-3/MSM-2.

c. Calibration Procedures for Decibel Meters. Calibrate decibel meters in accordance with the instructions covering rectifier types (par. 36a). Because decibel meters are calibrated in arbitrary values rather than in terms of voltage, it will be necessary to determine the voltage required to deflect the meter to the various scale calibration marks. Determine this voltage by using the formula $V = \sqrt{PR}$, where V is the unknown voltage, P is the power in watts, and R is the resistance of the load across which the meter is designed to operate.

Example: Assume that the reference level of a meter is 0 decibels at 5 mw (milliwatts) and that the meter is used across an 800-ohm load. The voltage required to deflect the meter to 0 decibels is found by substituting as follows in the formula:

$$V = \sqrt{PR} = \sqrt{.005 \times 800} = \sqrt{4} = 2.$$

37. Calibration of Frequency Meters

All frequency meters should be calibrated while a voltage of variable frequency is applied. Use Frequency Meter FR-40/GSM-1 as a standard for calibration.

Note. If a laboratory method of calibration is to be used, connect the meter to the circuit of a variable-speed alternator or generator, to an inverted rotary converter, or to some similar device. Check the scale points by comparing them with a standard frequency meter of known accuracy connected to the same circuit, by calculating the frequency of a known accuracy connected to the same circuit, or by calculating the frequency with a tachometer or with a revolution counter and stop watch. If a tachometer or revolution counter is used, insert the shaft in the end of the generator shaft. When a tachometer is used, the speed is indicated directly, but when a revolution counter and stop watch are used, the number of revolutions per minute must be counted. The tachometer must be capable of reading to within plus or minus 1 rpm (revolution per minute), and the error should not exceed plus or minus 1 rpm at 1,200 rpm or plus or minus 4 rpm at 3,600 rpm. To convert rpm into cps (cycles per second), apply the following formula: $F = \frac{PS}{120}$, where F is the frequency, P is the number of poles in the machine, S is the speed in rpm, and 120 is the constant. If the number of poles in the machine is unknown, determine the frequency from the nameplate, and apply the above formula in reverse, as follows:

$P = \frac{120F}{S}$. For example, if the nameplate indicates a frequency of 60 cycles at 1,200 rpm, the number of poles is: $P = \frac{120F}{S} = \frac{120 \times 60}{1,200} = 6$.

a. Calibration of Moving-Coil Type Frequency Meters.

- (1) Check the balance of the movement.
- (2) Connect the meter to a voltage source of variable frequency. Adjust the applied frequency to the nominal indicated value of the meter: 25 cycles for a 20- to 30-cycle meter and 60 cycles for a 58- to 62-cycle meter.
- (3) The meter must indicate the applied frequency within its rated accuracy tolerance.
- (4) If the reading is not within the tolerance, a minor calibration adjustment may be made by adjusting the iron core of the reactor in the resonant circuit.

b. Calibration of Iron-Vane Type Frequency Meters.

- (1) Perform the steps described in a(1) and (2) above.

- (2) The meter must indicate the applied frequency within its rated accuracy tolerance.
- (3) If the reading is not within the tolerance, a minor calibration adjustment may be made by changing resistor values or by adjusting the iron cores in the reactors. Resistor values may be changed either by substituting new values or by adding or removing wire from the spool. To change the reactance, loosen the nuts at the top and raise or lower the iron cores. *After adjusting the cores, tighten all nuts and bolts.*

c. Calibration of Vibrating-Reed Type Frequency Meters.

- (1) Connect the meter to a voltage source of variable frequency. It will not be necessary to balance the movement. Follow the procedure given in *a*(2) above.

Note. Reeds adjacent to the reed that indicates the applied frequency will vibrate. Vibration of a reed begins at about 2 percent below and extends to about 2 percent above the applied frequency. The applied frequency may be estimated from the comparative amplitudes of vibration of the various reeds. The reed (or reeds) having the greatest amplitude of vibration is the reed (or reeds) most nearly resonant at the applied frequency. By comparing the amplitudes of vibration of two or more reeds, the frequency may be estimated to within .5 percent.

- (2) Do not attempt to calibrate individual reeds. This is a critical operation and requires frequencies that are accurate to within .02 cycle. If the frequency indication is not within .5 percent, check the reeds for dirt, shellac, solder, or other matter, and carefully remove any such material adhering to them. *Do not file the reeds or add solder to change their resonant frequency.*
- (3) Check the coils and series resistors for continuity. Replace any that are defective.
- (4) On dual-range instruments, check the range switch for defective contacts. Replace it if necessary.
- (5) Do not change the value of the series

resistor, because it functions as a current-limiting device and adapts the meter to specified voltages.

- (6) When a meter cannot be calibrated by the above procedure (*c*(1) through (5) above), replace defective parts as required.

38. Testing Complete Instrument after Repaired Meter Has Been Reinstalled

a. General. If the repaired meter fails to indicate or indicates incorrectly, trace the source of the trouble by checking other components in the test instrument of which the meter is a part. One of the chief causes of trouble is incorrect connections. It is beyond the scope of this manual to give the correct connections for every type of instrument. When disassembling an instrument, make careful notes or drawings of the connections to insure that the proper connections will be made during reassembly.

b. Meter Fails to Indicate. Be sure that circuit terminals are tight and that they make contact. Check for opens, shorts, broken joints, dirty switch contacts, and defective tubes.

c. Meter Reads Low. Partial shorts, dirty connections, or poor contacts will cause a meter to read low. In voltmeters, low readings also may be caused by a multiplier resistor of too high a value. Be sure that the serial number of the meter and of the resistor is the same. In ammeters with external shunts, a low reading may be caused by a shunt of the wrong value.

d. Meter Reads High. In voltmeters, a high reading generally is caused by a short circuit in resistance spools. To find a short circuit, check the resistance of each spool with an ohmmeter. A high reading is seldom encountered in an ammeter, but may result from the use of a shunt of the wrong value or from a short between the shunt leads and the instrument.

e. Meter Reading is Erratic. Erratic reading may be caused by poor circuit connections or by an intermittent short or open circuit. Check all connections for cleanliness and tightness before marking an instrument "Repaired".

f. Meter Reads Backward. If a meter reads backward, reverse its connections.

39. Internal Resistance of Meters

The internal resistance of meters should be changed only by the amount required to bring the meter reading at full scale within the specified accuracy of the meter. If the required internal resistance of the meter is unknown, it may be calculated by Ohm's Law, provided that the voltage and current required to produce full-scale deflection are known. If neither the full-scale current nor the voltage is known, use the following procedure to determine the correct internal resistance:

a. Connect the meter to a variable voltage standard.

b. Apply the voltage required to produce full-scale deflection, and record the value of the voltage.

Caution: When the full-scale voltage of the meter is unknown, set the variable standard at a low value to avoid damage to the meter movement.

c. Disconnect one lead from the meter and insert a variable decade resistance in series with the lead. *Set the variable decade at a high range.*

d. Apply *exactly twice* the voltage recorded in b above.

e. Adjust the variable decade resistance until the meter reads full-scale deflection.

f. The value indicated on the decade is the internal resistance of the meter.

40. Weatherproofing

a. *General.* Signal Corps equipment, when operated under severe climatic conditions such as prevail in tropical, arctic, and desert regions, requires special treatment and maintenance. Fungus growth, insects, dust, corrosion, salt spray, excessive moisture, and extreme temperatures are harmful to most materials.

b. *Tropical Maintenance.* A special moisture-proofing and fungiproofing treatment has been devised which, if properly applied, provides a reasonable degree of protection. This treatment is explained fully in TB SIG 13 and TB SIG 72.

c. *Winter Maintenance.* Special precautions necessary to prevent poor performance or total operational failure of equipment at extremely low temperatures are explained fully in TB SIG 66 and TB SIG 219.

d. *Desert Maintenance.* Special precautions necessary to prevent equipment failure in areas subject to extremely high temperatures, low humidity, and excessive sand and dust are explained fully in TB SIG 75.

e. *Lubrication.* The effects of extreme cold and heat on materials and lubricants are explained in TB SIG 69. Observe all precautions outlined in TB SIG 69 and pay strict attention to all lubrication orders when operating equipment under conditions of extreme cold or heat.

Section III. MAINTENANCE EQUIPMENT

41. Meter Test Equipment AN/GSM-1B (fig. 42)

a. *Purpose.* Meter Test Equipment AN/GSM-1B is designed to provide complete facilities for checking the operation and accuracy of a-c and d-c ammeters and voltmeters, for checking the accuracy of frequency meters and ohmmeters, and for correcting the magnetic fields of meter magnets.

b. *Major Components.* Meter Test Equipment AN/GSM-1B consists of Meter Test Set TS-682/GSM-1 ((1) below) and the additional components listed in (2) below.

(1) Meter Test Set TS-682/GSM-1 includes the following components:

- (a) Meter test set (fig. 43).
- (b) Two Mountings MT-135A/GSM-1 (figs. 44 and 45).
- (c) One set of calibration rings (fig. 43).
- (d) One Cord CX-25A/GSM-1, one Cord CX-25B/GSM-1, one cord terminated in Plug PL-55 at one end and a spade lug at the other end, one cord terminated in Plug PL-68 at one end and a spade lug at the other

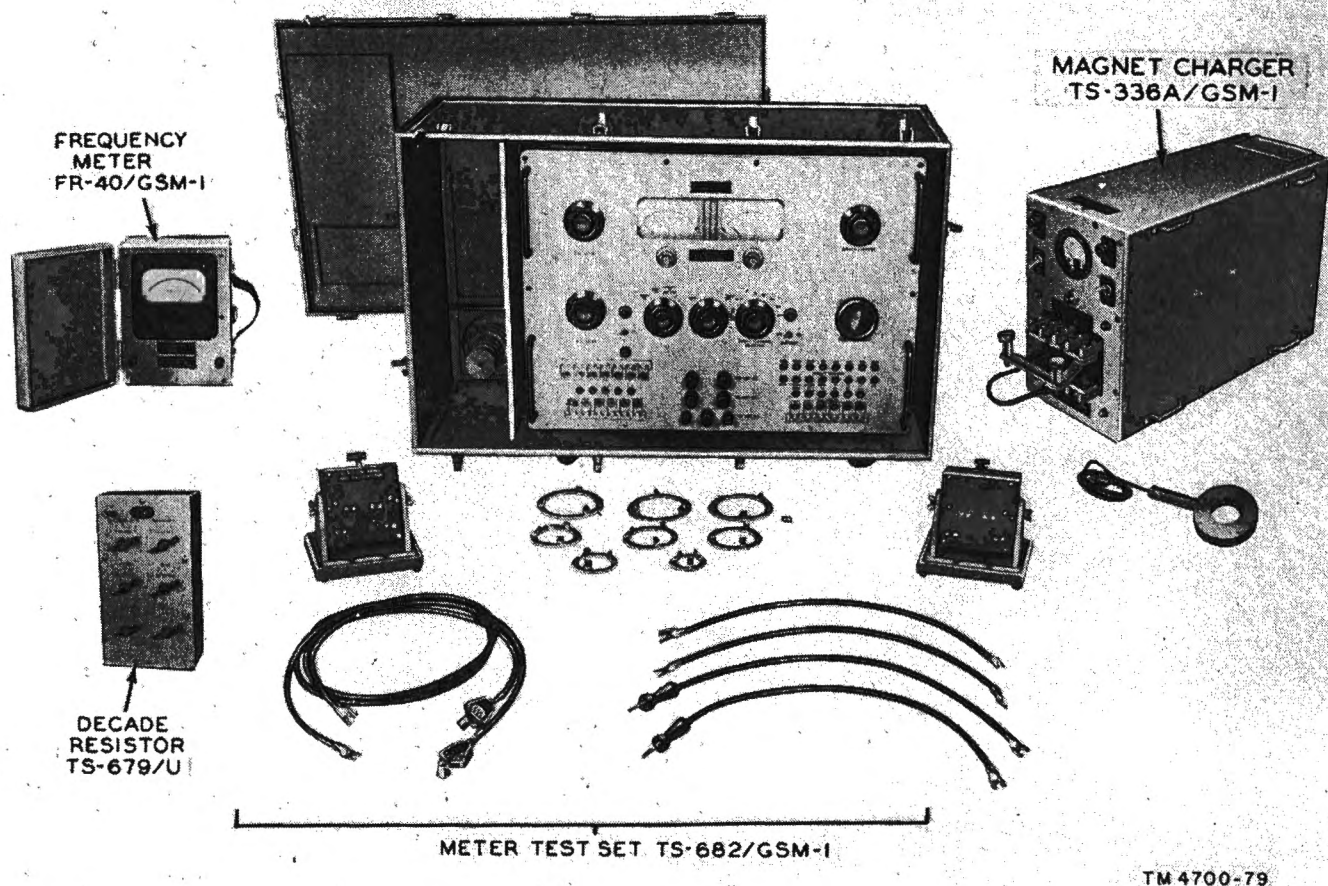


Figure 42. Meter Test Equipment AN/GSM-1B. (Test Set I-49, Multimeter TS-352/U, Tube Tester I-177-(), Tube Socket Adapter Kit MX-949()/U, and Resistance Bridge ZM-9()/U not shown.)

end, and two cords with each end terminated in a spade lug (fig. 43).

(e) Case CY-721/GSM-1.

(2) The additional components of Meter Test Equipment AN/GSM-1B are:

(a) Magnet Charger TS-336A/GSM-1 (figs. 46 and 47), with demagnetizing coil (fig. 48).

(b) Frequency Meter FR-40/GSM-1 (fig. 49).

(c) Decade Resistor TS-679/U (fig. 50).

(d) Test Set I-49.

(e) Multimeter TS-352/U.

(f) Tube Tester I-177-().

(g) Tube Socket Adapter Kit MX-949()/U.

(h) Resistance Bridge ZM-9()/U.

c. *Reference.* For complete details on the circuits and specific characteristics of this equip-

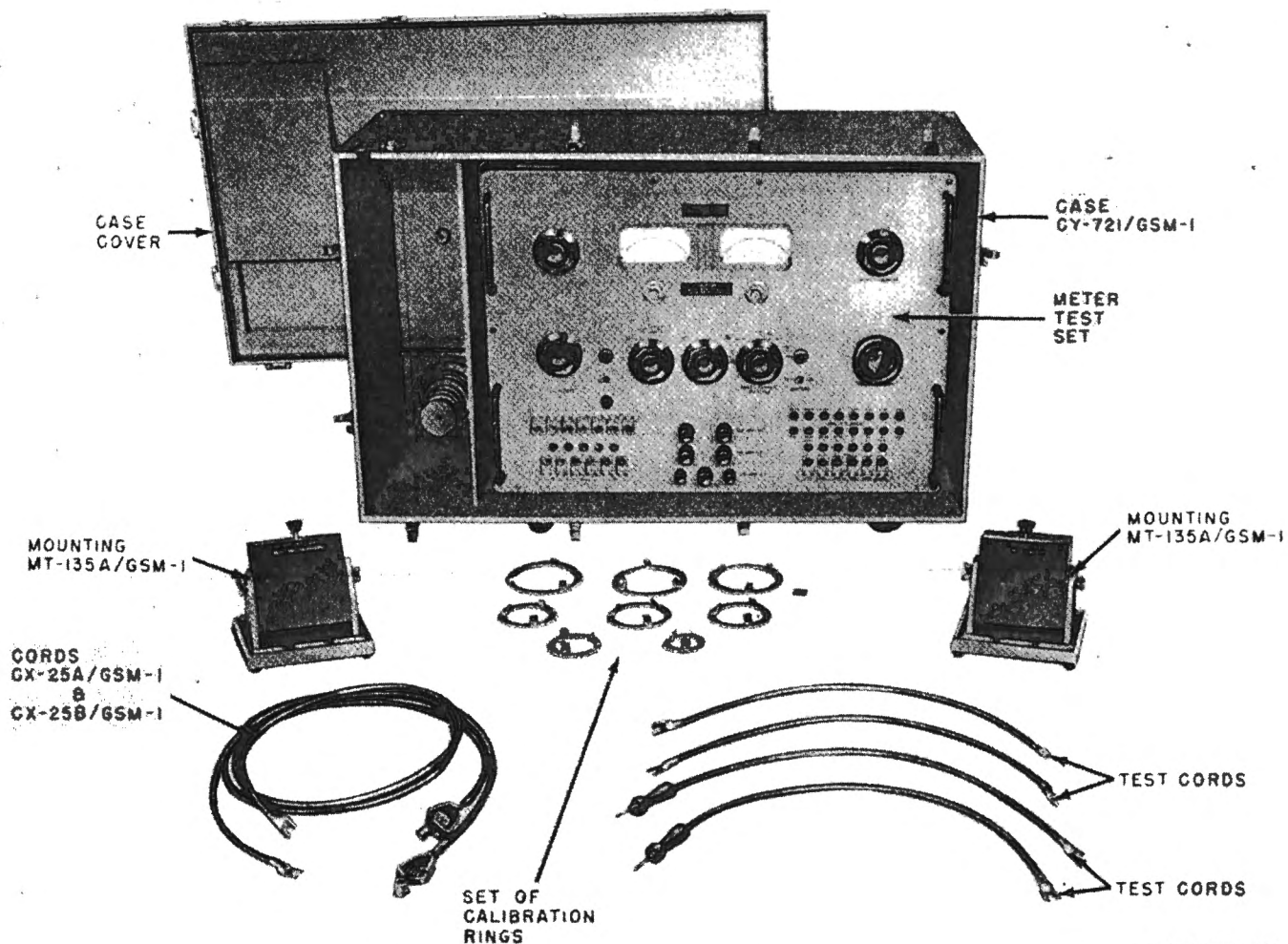
ment, refer to TM 11-2535A, Meter Test Equipment AN/GSM-1B.

42. Use of Calibration Rings

Many meters used by Army personnel are mounted on steel panels. When this type of meter is tested and calibrated separately from the equipment in which it is used, a calibration ring must be used. Select a ring of the approximate diameter of the meter to be tested, and slip it over the body of the meter before mounting the meter in Mounting MT-135A/GSM-1.

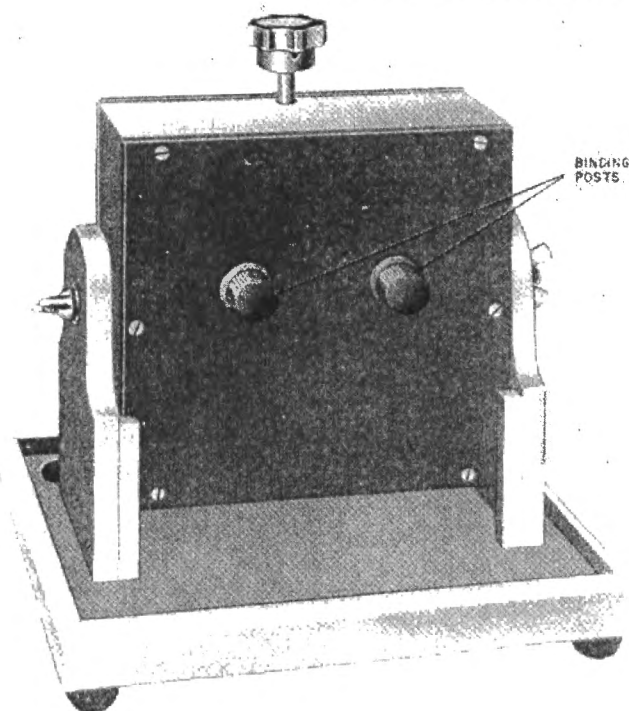
43. Test Procedures

a. *D-C Voltmeter Checks With Meter Test Set TS-682/GSM-1.* The following procedure is given for a 75-volt d-c voltmeter. The same operating principles apply to the testing of voltmeters of other ranges.



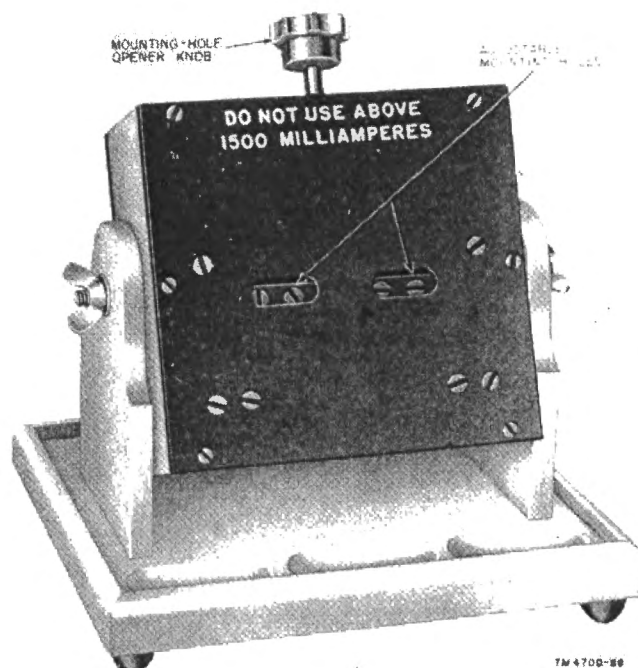
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Figure 43. Meter Test Set TS-682/GSM-1, components.



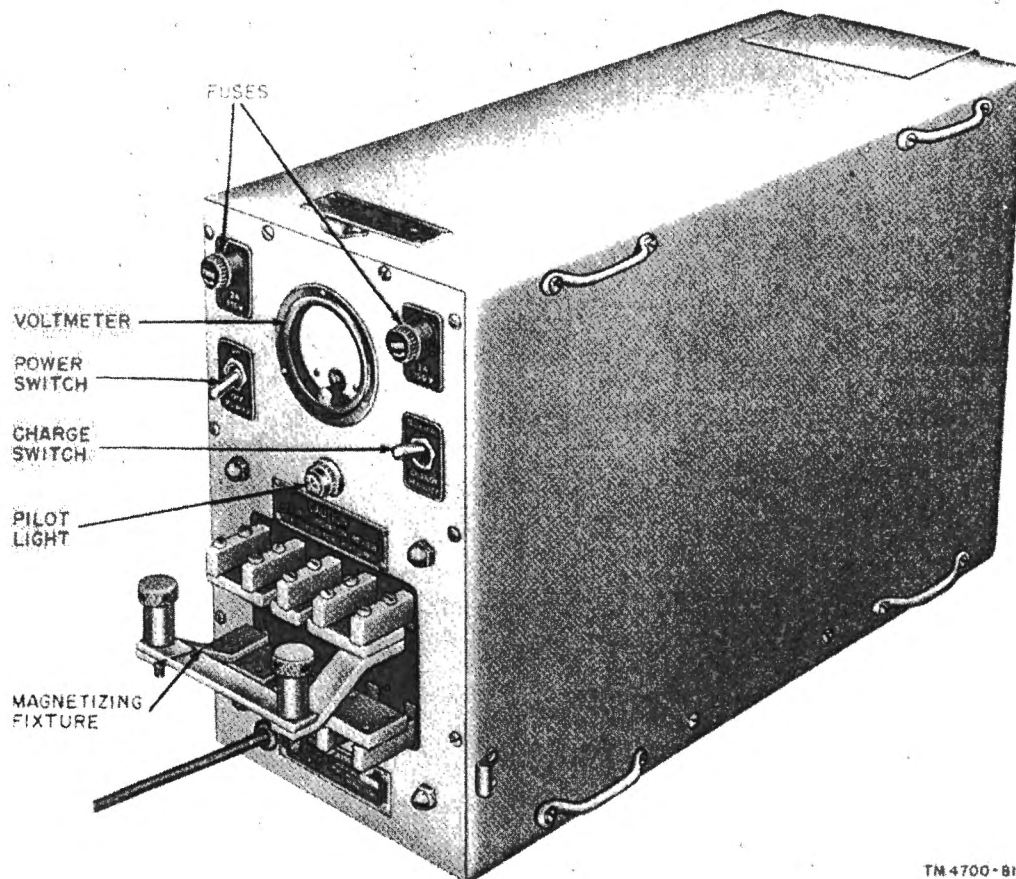
TM 4700-78

Figure 44. Mounting MT-135A/GSM-1, front view.



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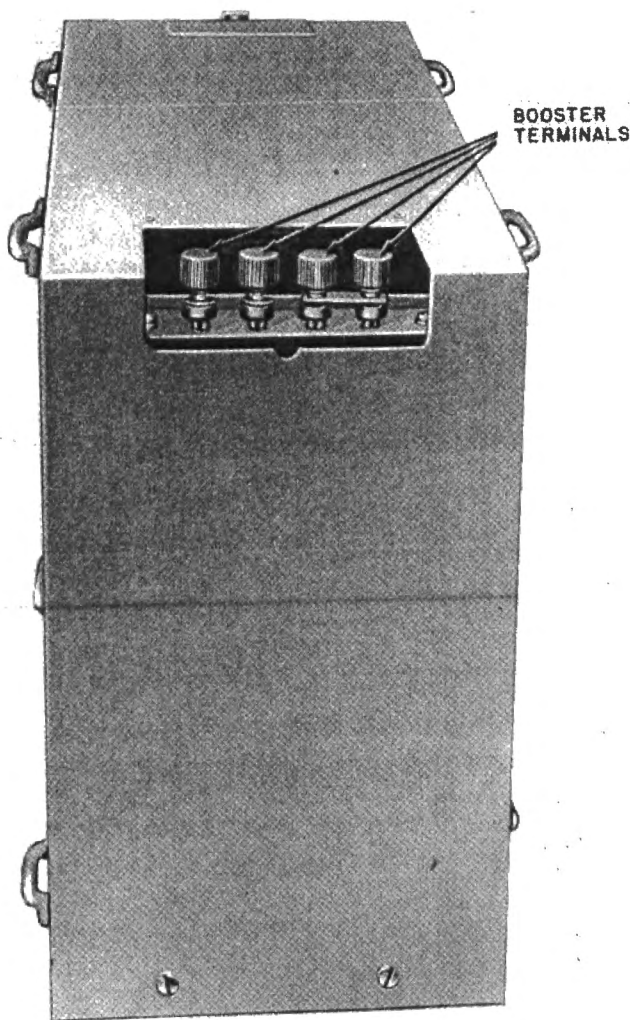
Figure 45. Mounting MT-135A/GSM-1, rear view.



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Figure 46. Magnet Charger TS-336A/GSM-1, front view.

- (1) Check all control knobs to make sure that each is in the extreme counter-clockwise position.
 - (2) Throw the AC LINE switch to the ON position. Allow 15 minutes for the equipment to warm up.
 - (3) Turn range switch S4 to the DCV position. Set range switch S5 at the 100 MVD.C. TO 400 V.D.C. position.
 - (4) Connect the spade end of the test cord that has Plug PL-55 at the other end to the negative terminal at the rear of Mounting MT-135A/GSM-1. Connect one spade end of the cord that has two spade ends to the positive terminal at the rear of Mounting MT-135A/GSM-1 and connect the other end to the COMMON binding post on the meter test set.
 - (5) Press down on the knob at the top of the meter mounting and place the meter under test in the mounting.
 - (6) Insert plug PL-55 into the 100 V d-c voltage jack.
 - (7) Slowly rotate the DC VOLTS COARSE CONTROL clockwise until the pointer of the standard d-c meter (M1) reaches 75 volts on the scale nearest the bottom of the meter.
 - (8) Make a fine adjustment of the scale reading by rotating the DC VOLTS FINE CONTROL.
 - (9) Compare the reading of the meter under test with that of the standard d-c meter.
 - (10) Repeat the procedure outlined in (7), (8), and (9) above for the voltage value marked at each cardinal division to check the action and accuracy of the meter under test.
- b. D-C Ammeter Checks With Meter Test Set TS-682/GSM-1. The following procedure is given for a 75-ampere d-c ammeter. The



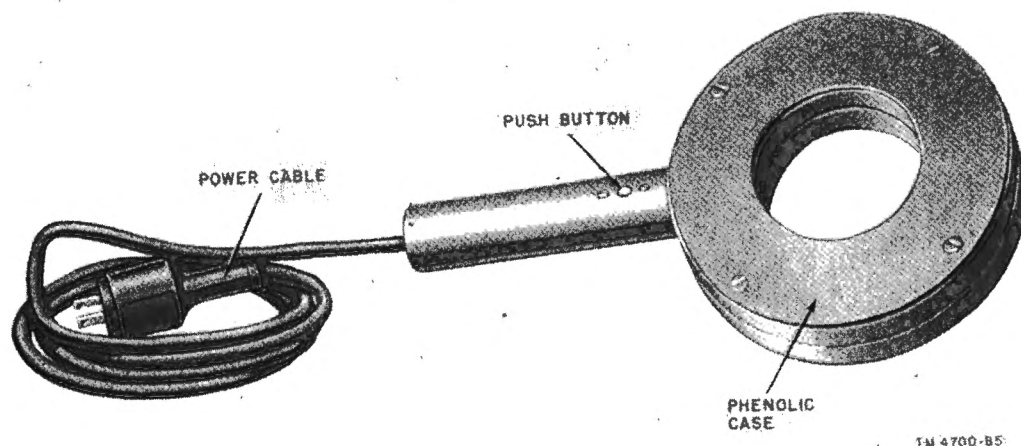
TM 4700-82

Figure 47. Magnet Charger TS-336A/GSM-1, rear view.

same operating principles apply to the testing of ammeters of other ranges.

- (1) Check all controls to make sure that each is in the extreme counterclockwise position.
- (2) Use the test leads that have a spade lug on each end to connect the negative and positive terminals of the meter under test to the COMMON and 100 AMP D.C. binding posts, respectively, of Meter Test Set TS-682/GSM-1.
- (3) Turn the DIRECT CURRENT SELECTOR switch to the 100A position.
- (4) Throw the BATTERY switch to the ON position.
- (5) Slowly turn the DIRECT CURRENT COARSE CONTROL clockwise until the standard d-c meter (M1) of Meter Test Set TS-682/GSM-1 reads 75 amperes.
- (6) Make a fine adjustment of the scale reading by rotating the DIRECT CURRENT FINE CONTROL.
- (7) Compare the reading of the meter under test with the reading of the standard d-c meter.
- (8) Repeat the procedure outlined in (5), (6), and (7) above for currents of $\frac{3}{4}$, $\frac{1}{2}$, and $\frac{1}{4}$ of the full-scale value to check the action and accuracy of the meter under test.

c. A-C Voltmeter Checks With Meter Test Set TS-682 GSM-1. The following procedure is given for a 150-volt a-c voltmeter. The same



TM 4700-85

Figure 48. Demagnetizing coil.

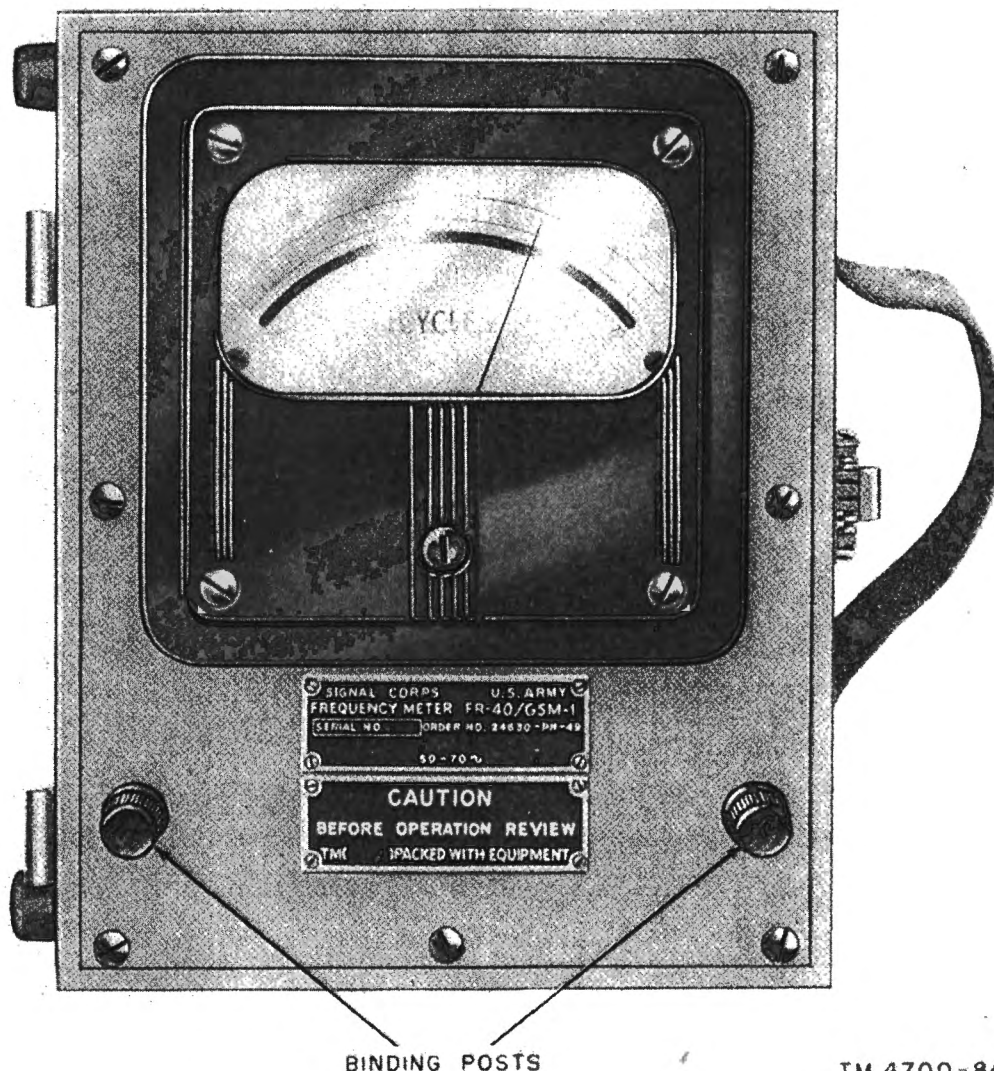


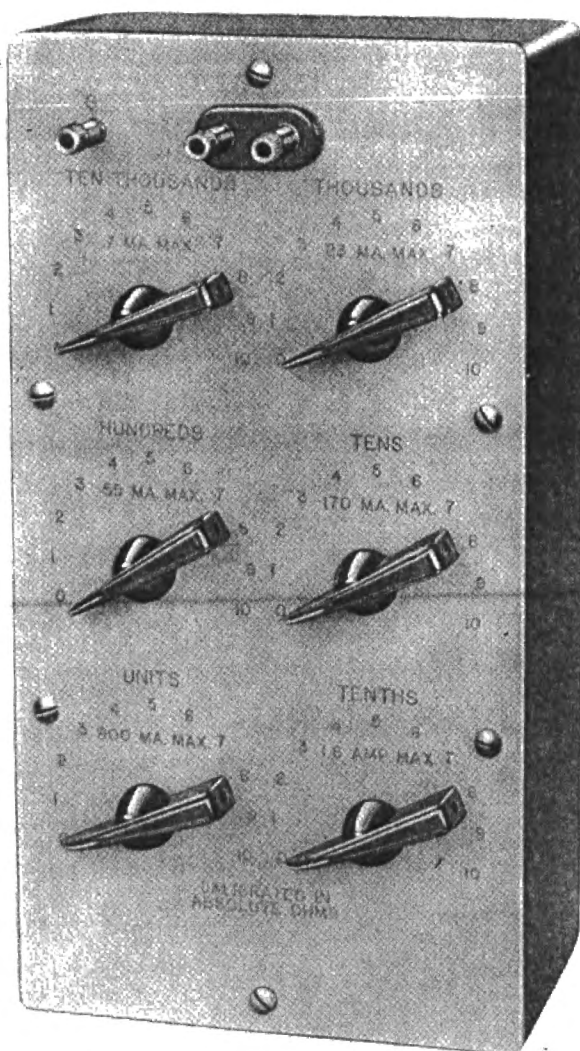
Figure 49. Frequency Meter FR-40/GSM-1.

operating principles apply to the testing of voltmeters of other ranges.

- (1) Check all control knobs to make sure that each is in the extreme counter-clockwise position.
- (2) Throw the AC LINE switch to the ON position, and allow 15 minutes for the equipment to warm up.
- (3) Turn range switches S4 and S5 to the A.C.V. position.
- (4) Connect the spade lug of the test cord that has Plug PL-55 at the other end to either terminal at the rear of Mounting MT-135A/GSM-1. Connect one end of the test cord that has a spade lug at each end to the other terminal at the rear of Mounting MT-135A/

GSM-1, and connect the other end to the COMMON binding post of Meter Test Set TS-682/GSM-1.

- (5) Press down on the knob at the top of Mounting MT-135A/GSM-1, and place the meter under test in the mounting.
- (6) Insert plug PL-55 into the 200V a-c voltage jack.
- (7) Slowly rotate the AC VOLTS COARSE CONTROL clockwise until the pointer of the standard a-c meter (M2) reaches 150 volts on the middle scale.
- (8) Make a fine adjustment of the scale reading by rotating the AC VOLTS FINE CONTROL clockwise.



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Figure 50. Decade Resistor TS-679/U.

- (9) Compare the reading of the meter under test to the reading of the standard meter.
- (10) Repeat the procedure outlined in (7), (8), and (9) above for voltage values of 111, 75, and 37 to check the action and accuracy of the meter under test.

d. *A-C Ammeter Checks With Meter Test Set TS-682/GSM-1.* The following procedure is given for a 10-ampere a-c ammeter. The same operating principles apply to the testing of ammeters of other ranges.

- (1) Check all control knobs to make sure that each is in the maximum counter-clockwise position.
- (2) Throw the AC LINE switch to the ON position.

- (3) Connect the spade end of the test cord that has Plug PL-68 at the other end to either terminal at the rear of Mounting MT-135A/GSM-1. Connect one end of a test cord with a spade lug at each end to the other terminal at the rear of Mounting MT-135A/GSM-1, and connect the other end to the COMMON binding post of Meter Test Set TS-682/GSM-1.
- (4) Press down on the knob at the top of Mounting MT-135A/GSM-1 and place the meter under test in the mounting.
- (5) Insert Plug PL-68 into the 10A a-c jack on Meter Test Set TS-682/GSM-1.
- (6) Slowly turn the ALT. CURRENT COARSE CONTROL clockwise until the standard a-c meter (M2) reads 10 amperes (full-scale deflection, on the bottom scale, divided by 10).
- (7) Make a fine adjustment of the reading by rotating the ALT. CURRENT FINE CONTROL.
- (8) Compare the reading of the meter under test with the reading of the standard meter.
- (9) Repeat the procedure outlined in (6), (7), and (8) above for currents of 7, 5, and 3 amperes to check the action and accuracy of the meter under test.

44. Resistance Measurement

a. *Decade Resistor and Wheatstone Bridge.* To determine resistance values of the series resistors, multipliers, and shunts used with the meters, refer to TM 11-5520. If greater accuracy is desired, use Test Set I-49 (TM 11-2019). This bridge is simple in construction, easy to operate, and conveniently portable for shop use.

b. *Ohmmeter.* The ohmmeter is a portable, self-contained instrument used for measuring resistance and for locating opens, shorts, and grounds in electrical circuits. It has a moving-coil movement similar to that of a voltmeter and a removable dry-cell battery which usually is located inside the case of the instrument. (In many instruments, the same meter is adapted to read voltage, amperage, and resistance by the use of multiple-position multipolar switches

which select the proper function and range.) The meter of the ohmmeter and its source of voltage are connected so that the resistance of a conductor between the two test leads can be read directly on a scale calibrated in ohms. This instrument is less accurate than the Wheatstone bridge; however, it is used where great accuracy is not necessary, because of its simplicity and convenience.

Caution: Never place the test leads of an ohmmeter across the terminals of a microammeter. The dry cell in the ohmmeter delivers more current than a microammeter can carry.

45. Magnet Charger TS-336A/GSM-1 (figs. 46 and 47).

a. *Purpose.* The magnet charger is used to remagnetize meter magnets, and the demagnetizing coil is used to reduce the magnetism for correct calibration. To fabricate an expedient magnet charger, refer to appendix II.

b. *Construction.* The magnet charger is essentially a capacitor-discharge impulse charger. It is contained in a compact metal case.

c. *Operation.* To operate the magnet charger, proceed as follows:

- (1) Plug the cord into a 110- to 120-volt, 50- to 60-cycle outlet.
- (2) If the polarity of the meter magnet is unknown, check it by using a small compass.
- (3) If the magnet cannot be removed from the meter case without removing the moving element, place a keeper across the magnet. Insert the magnet in charging position (fig. 51) as follows:
 - (a) Loosen the two binding screws that hold the charging bar and remove the charging bar.
 - (b) Insert the charging bar through the meter-magnet window so that the south pole of the meter magnet is uppermost, and tighten the two binding screws to secure the bar in place. If the mechanical construction of the magnet requires that the poles be placed away from the panel, place the north pole uppermost.
- (4) Throw the POWER switch to the ON position.

- (5) When the equipment has warmed up and is ready to charge the magnet, the meter will read 500 volts. When the meter reads 500 volts, hold the MAGNET switch down in CHARGE position.

Caution: The magnetic charge will extend out nearly 5 feet from the magnet charger; therefore, do not permit any device that is sensitive to magnetism, such as a watch or other instrument, to come within the magnetic area while the charger is operating.

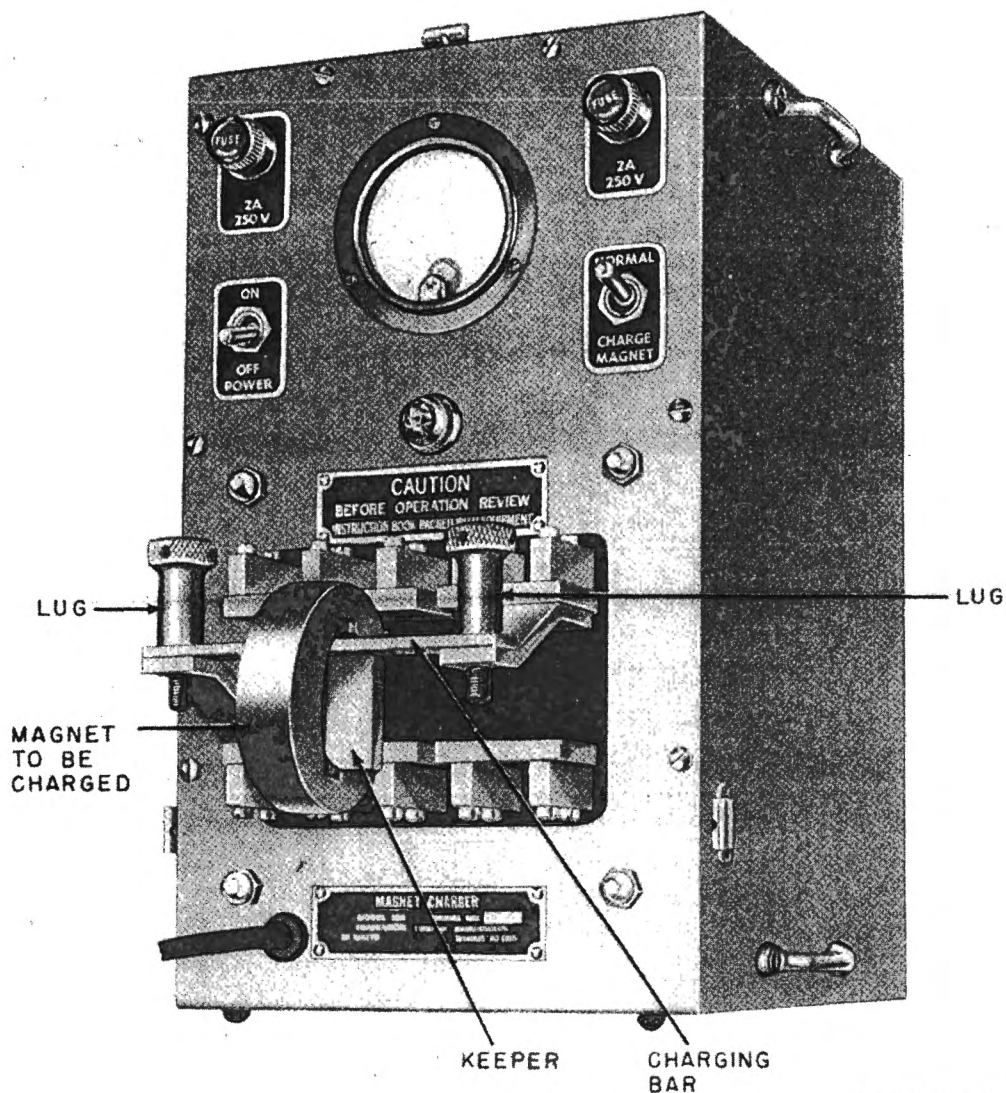
- (6) After a period of approximately 3 seconds, allow the MAGNET switch to return to NORMAL position.
- (7) Throw the POWER switch to the OFF position.
- (8) Remove the charged magnet from the charger fixture. Do not remove the keeper, if one was used, until the movement has been installed in the meter magnet.

46. Demagnetizer (fig. 48)

a. *Purpose.* Meter magnets charged by the magnet charger will be magnetized too highly and must be *bucked down* by the demagnetizing coil. This coil produces an alternating magnetic field which slightly disturbs the uniformity of the molecular arrangement of the magnet to reduce its strength.

b. *Operation.*

- (1) Connect the demagnetizing coil to a 105- to 125-volt, 60-cycle power source by use of the attached power cord.
- (2) Actuate the charged meter by placing it in testing position (par. 35a(4)).
- (3) Set the appropriate standard meter of the meter test set at approximately three-fourths of full-scale deflection. Compare the reading of the newly charged meter with the reading of the standard meter. The reading of the meter under test will be too high.
- (4) Hold the demagnetizing coil approximately 2 feet from the case of the meter being calibrated.



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Figure 51. Magnet to be charged in charging position.

Caution: Keep the demagnetizing coil at least 2 feet away from the meter test set, so that the accuracy of the standard meters will not be affected.

- (5) Depress the push button on the handle of the demagnetizing coil and bring the coil progressively closer to the meter under calibration until its reading agrees with the reading of the standard meter of the test set. If stronger transient demagnetizing currents are needed, alternately and at a rapid rate, depress and release the push button on the demagnetizer.

Caution: Do not depress the push button for too long a time. The demagnetizing coil heats up very rapidly.

47. Frequency Meter FR-40/GSM-1 (fig. 49)

To determine the accuracy of a power frequency meter, proceed as follows:

- a. Connect the meter to be tested across a 115-volt, 60-cycle (± 10 cycles) power source.
- b. Connect Frequency Meter FR-40/GSM-1 to the same power source.
- c. Compare the reading of the standard meter with that of the meter under test.

CHAPTER 4

TESTING AND CALIBRATION OF STANDARD TEST SETS

Section I. VOLTMETERS AND AMMETERS

48. General

This section contains pertinent data essential to the repair of standard voltmeters and ammeters. Paragraphs 51 through 61 of this chapter contain the same type of information about the test sets covered therein. The information is presented as follows: The main paragraph heading gives the name of the equipment and its official nomenclature, as well as the technical manual covering the equipment; the text of the paragraph gives the sensitivity of the basic meter or other indicating device, the scale ranges of the instrument, specific calibration data, and the values of components that affect calibration. When applicable, the d-c information is given first, then the a-c and resistance measuring data. Specific circuit information is given in some cases to expedite the repair and calibration of a particular piece of test equipment. In most cases, the information applies to only one model of the equipment covered. For complete information on any equipment or on a particular model of that equipment, consult the technical manual or instruction book covering that equipment.

49. Voltmeter TS-363/U, TM 11-1239 (fig. 52)

a. Sensitivity. The sensitivity of the basic meter is 200 μ a (microampere) dc for full-scale deflection plus or minus 2 percent.

b. Checking Voltage Ranges.

- (1) Select the 1-volt d-c range. Apply full-scale voltage from Meter Test Set TS-682/GSM-1, and compare the reading of the meter in Voltmeter TS-363/U with that of the standard d-c meter.

The readings should agree within plus or minus 2 percent.

- (2) Repeat (1) above for the 3-, 10-, 30-, and 100-volt d-c ranges.
- (3) Select the 1-volt a-c range. Apply full-scale voltage from Meter Test Set TS-682/GSM-1, and compare the reading of the meter in Voltmeter TS-363/U with that of the standard a-c meter. At 60 cycles, the reading of Voltmeter TS-363/U will be 4 percent lower (plus or minus 2 percent) than that of the standard a-c meter.
- (4) Repeat (3) above for the 3-, 10-, 30-, and 100-volt a-c ranges.

Note. Because of the nature of the circuit arrangement on ac, the 1-volt range requires recalibration whenever tubes are changed.

- (5) Preset adjustments are provided for all a-c and d-c ranges except the 100-volt range. The adjustable resistors (fig. 52) for the various ranges are as given in the table below.

Range	Dc	Ac
1 volt	R7	R6
3 volts	R9	R8
10 volts	R11	R10
30 volts	R13	R12

- (6) If inaccuracies in excess of plus or minus 2 percent are observed in the readings of the meter, check the values of resistors R6 through R15.
- (7) There is no interaction between the calibration adjustments of the various

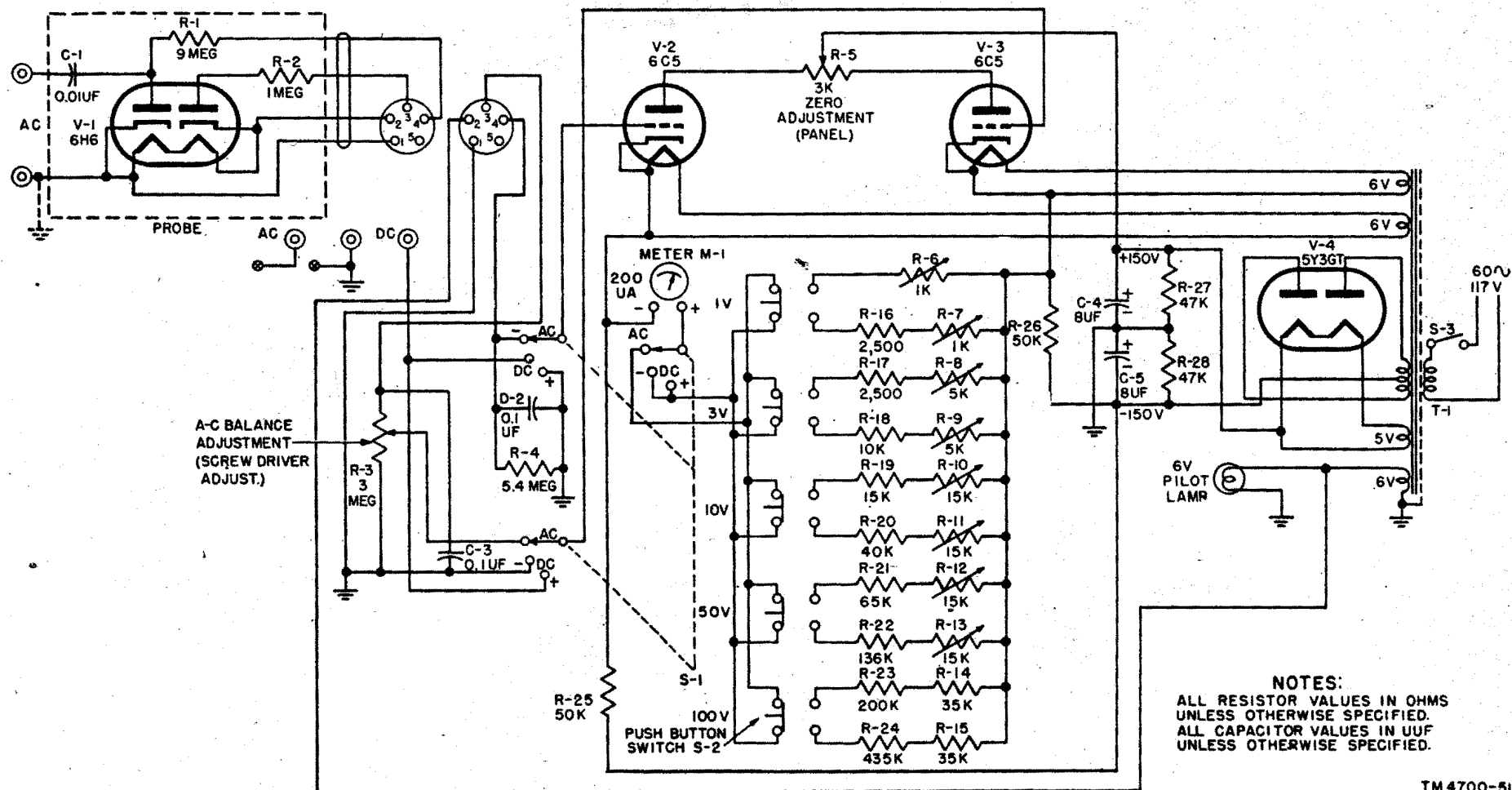


Figure 52. Voltmeter TS-363/U, schematic diagram.

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ranges. The ranges may, therefore, be calibrated in any order.

50. Voltammeter I-50 (Weston No. 280) (fig. 53)

a. Sensitivity. The sensitivity of the basic meter is .01 ampere with a nominal resistance of 2.5 ohms. The accuracy is within plus or minus 1 percent.

b. Checking Voltage Ranges.

- (1) Press the PRESS FOR VOLTAGE control, and turn it $\frac{1}{4}$ turn. Connect suitable test cords from Meter Test Sets TS-682/GSM-1 to the AMPS./VOLTS+ binding post and the appropriate range binding post of Voltammeter I-50.
- (2) Apply 3 volts dc from the meter test set. The value of this voltage must be determined by the use of the calibration cards packed in the rear shelf of the test set. Use of the cards will guarantee accuracy within plus or minus .25 percent, as compared with the direct accuracy of plus or minus 1 percent. Voltammeter I-50 should indicate a full-scale voltage reading of 3 volts plus or minus .25 percent. If the reading is less accurate, check resistor F (fig. 53). Its value should be 297.5 ohms plus or minus .1 percent.
- (3) Repeat (2) above for the 15- and 150-volt ranges. The resistor for the 15-volt range is 1,200 ohms; the resistor for the 150-volt range is 13,500 ohms.

c. Checking Current Ranges. This instrument includes a padding resistor and ring shunt circuit. The padding resistor is in series with

the meter on all current ranges, and, therefore, affects the accuracy on all current ranges. To check the current ranges, proceed as follows:

- (1) Release the PRESS FOR VOLTAGE control.
- (2) Apply current to the meter from Meter Test Set TS-682/GSM-1 and use the calibration cards to obtain the required accuracy for each range of Voltammeter I-50. The accuracy on all current ranges should be within plus or minus 1 percent.
- (3) If the accuracy is satisfactory, check resistance values between the taps of the shunt resistor. They should be as follows: from A to B, .00167 ohm; from B to C, .00167 ohm; from C to D, .01338 ohm. The padding resistor should have a value of 2.5 ohms plus or minus .05 ohm.

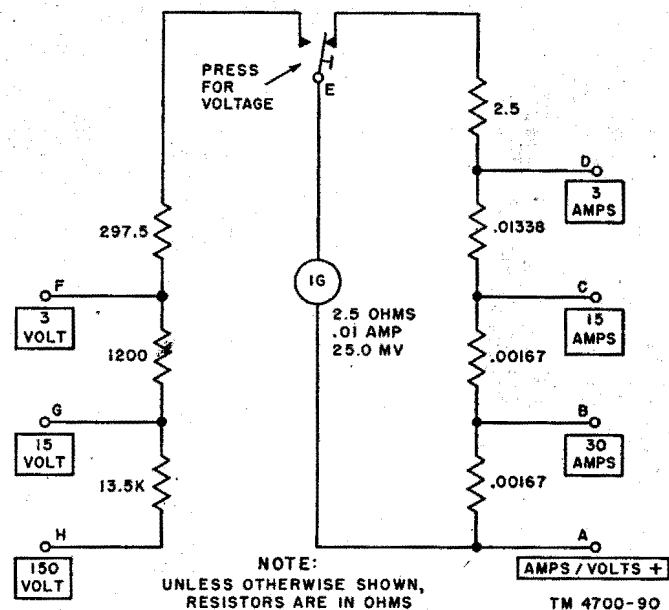


Figure 53. Voltammeter I-50.

Section II. MULTIMETERS

51. Multimeter TS-26/TSM, TM 11-2017 (fig. 54).

a. Sensitivity. The sensitivity of the basic meter is 100 μ a dc, and the internal resistance is 2,000 ohms.

b. Checking D-C Voltage Ranges.

- (1) With the VM-RES. switch in VM

position, apply 3, 30, 300, and 600 volts dc, successively, from Meter Test Set TS-682/GSM-1 to the appropriate jacks on the top of the front panel of Multimeter TS-26/TSM. The meter readings must agree with the readings of the standard d-c meter within plus or minus 2 percent.

- (2) If the readings of Multimeter TS-26/TSM disagree with those of the standard meter by more than plus or minus 2 percent, check the value of resistors R1 through R5 (fig. 54). The values of these resistors should be within plus or minus 1 percent of the specified values.

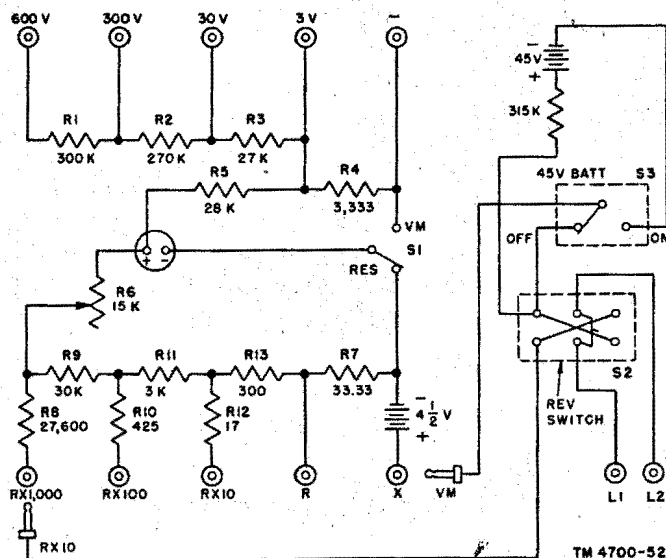


Figure 54. Multimeter TS-26/TSM, schematic diagram.

c. Checking Resistance Ranges. Since this instrument is used primarily in telephone line testing, it serves more as an ohmmeter than as a voltmeter. Therefore, a careful check of the resistance ranges is desirable. Proceed as follows:

- (1) Place the VM—RES. switch in the RES. position. Plug the short leads, VM- and RX10, into pin jacks X and R, respectively.
- (2) Throw the 45 V BATT switch to OFF position, and plug the long test leads into pin jacks L1 and L2.
- (3) Connect the test clips together, and adjust the battery adjustment knob to obtain a zero reading on the resistance scale of the meter (full-scale deflection). If the meter needle falls short of zero at the maximum clockwise setting of the battery adjustment knob, it will be necessary to replace the 4½-volt battery. The meter reading should be the same with the REV. SW switch in either position.

- (4) Remove the lead from pin jack R; plug it into pin jacks RX10, RX100, and RX1000, successively; and make a zero adjustment for each range. The meter resistors are connected in a network; failure of any one resistor will render the meter inoperative at all higher ranges.
- (5) If it is impossible to zero the meter for all scales, check the resistor associated with the lowest scale that will not zero.
- (6) Check the accuracy of the ohmmeter ranges by connecting the clips of the long leads to Decade Resistor TS-679/U. Use a value of resistance equal to one-half of the full-scale reading of the meter.
- (7) If inaccuracy of more than plus or minus 2 percent exists, check the value of resistors R6 through R13 (fig. 54). The values of these resistors should agree with the specified values within plus or minus 1 percent.

52. Multimeter TS-297/U, TM 11-5500 (fig. 55).

a. Sensitivity. The sensitivity of the basic meter in one model is 250 μ a dc plus or minus 2 percent, at 62.5 mv plus or minus 2 percent. In another model the sensitivity is 100 μ a, 80 mv.

b. Checking D-C Voltage Ranges (fig. 56).

- (1) Rotate the switch knob to the extreme clockwise position (DC).
- (2) Plug the test leads into the 4V and $\pm$ VOLTS —MA OHMS jacks.
- (3) Apply full-scale voltage from Meter Test Set TS-682/GSM-1, and compare the reading of the meter in Multimeter TS-297/U with that of the standard d-c meter. The readings should agree within plus or minus 3 percent.
- (4) Repeat (2) and (3) above for the 10V, 40V, 100V, 400V, and 1000V ranges.
- (5) If the readings of the meter in Multimeter TS-297/U disagree with those of the standard d-c meter by more than plus or minus 3 percent, check the values of resistors R1, R2, R4, R5, R14 through R21.

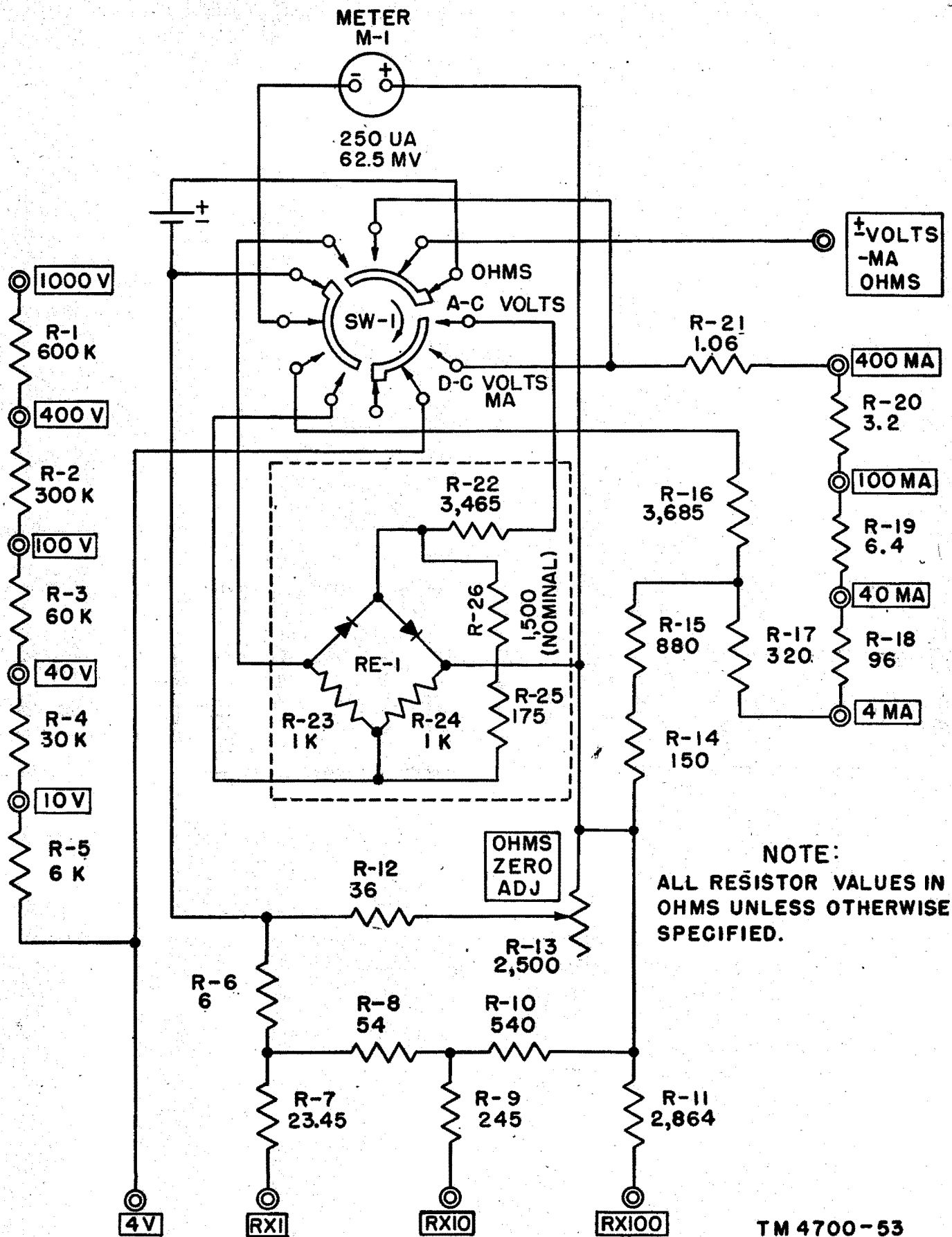
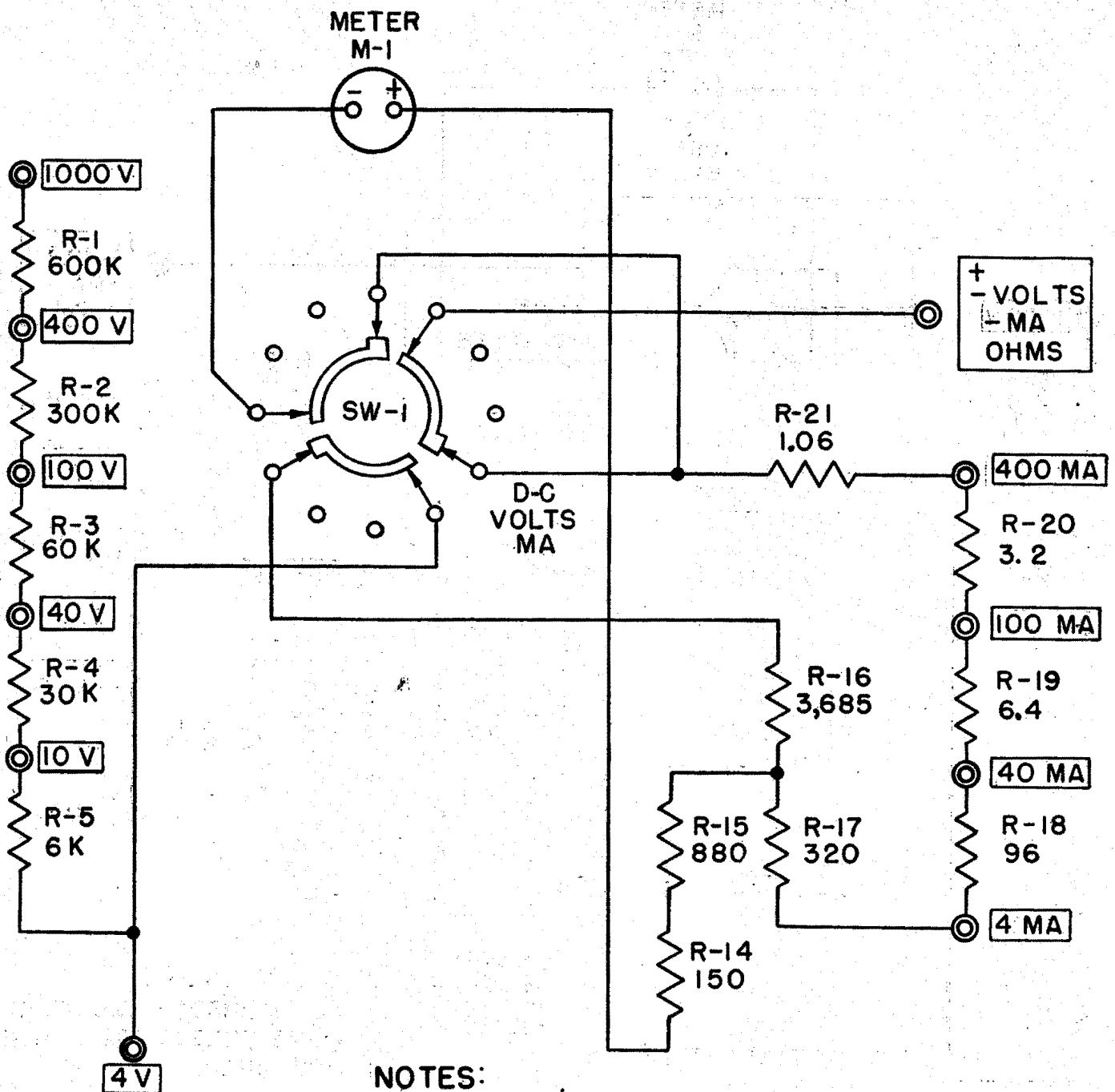


Figure 55. Multimeter TS-297/U, complete schematic diagram.



NOTES:
ALL RESISTOR VALUES IN OHMS
UNLESS OTHERWISE SPECIFIED.

TM 4700-54

Figure 56. Multimeter TS-297/U, schematic diagram, d-c voltmeter-milliammeter.

c. Checking A-C Voltage Ranges (fig. 57).

- (1) Rotate the switch knob to the center position (AC).
- (2) Plug the test leads into the 4V and $\pm$ VOLTS —MA OHMS jacks.
- (3) Apply full-scale voltage from Meter Test Set TS-682/GSM-1, and compare the reading of the meter in TS-297/U with that of the standard a-c meter.

The readings should agree within plus or minus 5 percent.

- (4) Repeat (2) and (3) above for the 10V, 40V, 100V, 400V, and 1,000V ranges.
- (5) If the readings of the meter in Multimeter TS-297/U disagree with those of the standard a-c meter by more than plus or minus 5 percent, check the values of resistors R1 through R5, R22

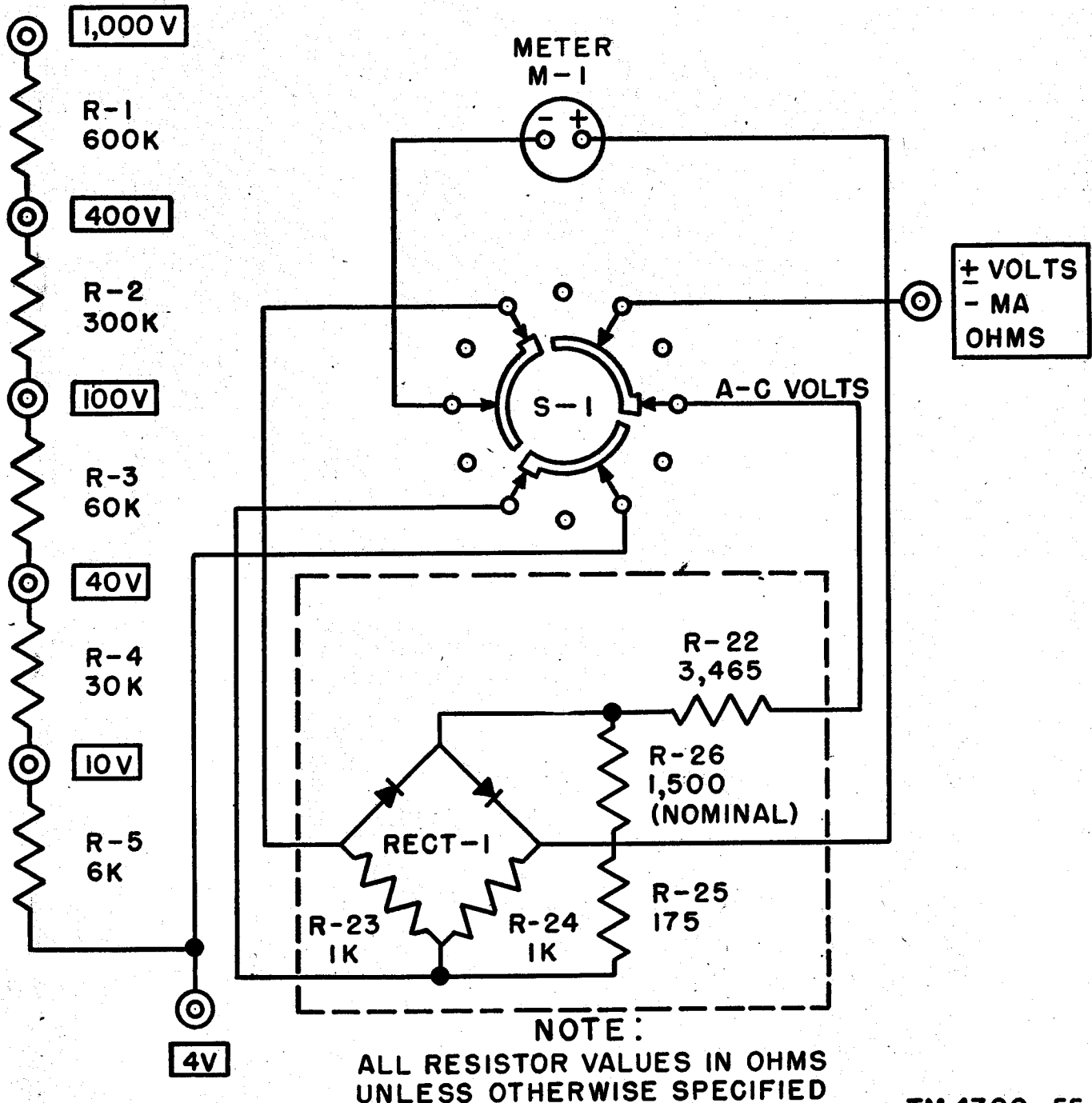
through R24, and R26. The values of these resistors should agree with the specified values within plus or minus 1 percent.

d. *Checking Current Ranges (DC)* (fig. 56).

- (1) Rotate the switch knob to the extreme clockwise position (DC).
- (2) Plug the test leads into the 4MA and $\pm$ VOLTS —MA OHMS jacks of Multimeter TS-297/U.

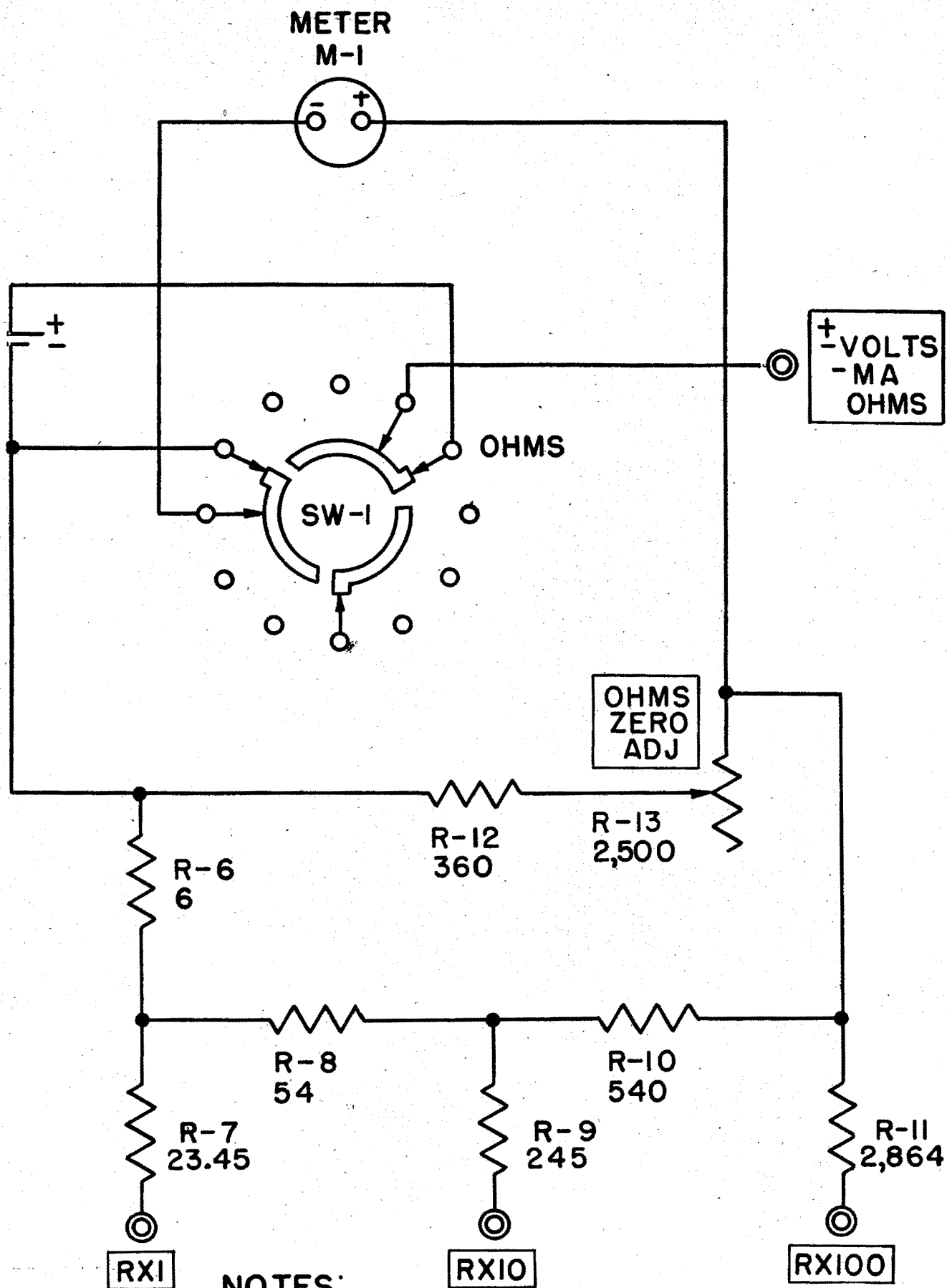
- (3) Apply the full-scale current from Meter Test Set TS-682/GSM-1, and compare the reading of the meter in Multimeter TS-297/U with that of the standard d-c meter. The readings should agree within plus or minus 3 percent.

- (4) Repeat (2) and (3) above for the 40MA, 100MA, and 400MA ranges.
- (5) If the readings disagree by more than



TM 4700-55

Figure 57. Multimeter TS-297/U, schematic diagram, a-c voltmeter.



NOTES:

ALL RESISTOR VALUES IN OHMS
UNLESS OTHERWISE SPECIFIED.

TM 4700-56

plus or minus 3 percent, check the values of resistors R14, R15, and R17 through R21. The values of these resistors should agree with the specified values within plus or minus 1 percent. Resistor R14 compensates for resistance variations in the circuit due to temperature changes.

e. Checking Resistance Ranges (fig. 58).

- (1) Rotate the switch knob to the extreme counterclockwise position (OHMS).
- (2) Plug the test leads into the RX1 and $\pm$ VOLTS —MA OHMS jacks.
- (3) Short the test leads together, and adjust the OHMS ZERO ADJUST control for full-scale deflection of the pointer.
- (4) Use Decade Resistor TS-679/U as a standard to check the meter reading produced by the half-scale value of resistance. Multimeter TS-297/U should indicate the value within plus or minus 5 percent of scale length.
- (5) Repeat (2) through (4) above for the RX10 and RX100 ranges.
- (6) If the meter reads with an error of more than 5 percent, check the values of resistors R6 through R13. Resistors R6 through R12 should agree with the specified values within plus or minus 1 percent. Resistor R13 has a tolerance of plus or minus 20 percent.

53. Multimeter TS-352/U, TM 11-5527 (fig. 59).

a. Sensitivity. The sensitivity of the basic meter is 50 μ a. The meter has a resistance of 1,700 ohms plus or minus 10 ohms and an 85-mv drop.

b. Checking D-C Voltage Ranges. This instrument has two input sensitivities, 1,000 ohms per volt and 20,000 ohms per volt; therefore, two separate voltage checks must be made.

- (1) Check the 1,000-ohm-per-volt range as follows:
 - (a) Turn the FUNCTION switch to the 1,000 Ω /VDC position. Plug the black lead into the —DC VOLTS jack. Plug the red lead into the 2.5V jack on the right-hand side of the panel.

- (b) Apply 2.5 volts dc from Meter Test Set TS-682/GSM-1.
- (c) The meter reading should be accurate within plus or minus 3 percent. If it is not, check the value of resistors R130 through R132, R134 through R138, R112, R129, R139A, and R139B.
- (d) Repeat the procedure above ((a) through (c)) for the remaining 1,000-ohm-per-volt ranges, inserting the red lead in the appropriate jack and applying full-scale values of voltage.
- (e) The table below gives resistor values and tolerances for the 1,000-ohm-per-volt ranges.

Range (v)	Resistor	Resistance (ohms)	Tolerance (%)
2.5	R130	2,310	.5
10	R101	7,500	.5
50	R102	40,000	.5
250	R103	200,000	.5
500	R104	250,000	.5
1,000	R105	500,000	.5

- (2) Check the 20,000-ohm-per-volt ranges as follows:
 - (a) Turn the FUNCTION switch to the 20,000 Ω /VDC position. Plug the black lead into the —DC VOLTS jack.
 - (b) Check all the 20,000-ohm-per-volt ranges except the 5,000-volt range by inserting the red lead in the appropriate jack on the left-hand side of the panel and applying the full-scale values of voltage. The accuracy should be within plus or minus 4 percent.
 - (c) To check the 5,000-volt d-c range, connect the 8-inch jumper lead between the low-potential jack of Multiplier Kit MX-815/U and the 2.5-volt jack at the left-hand side of the meter. Apply 2,000 volts dc from Meter Test Set TS-682/GSM-1. The meter in TS-352/U should read 2,000 volts plus or minus 6 percent.
 - (d) The table below gives resistor values and tolerances for the 20,000-ohm-per-volt ranges.

Range (v)	Resistor	Resistance value (ohms)	Tolerance (%)
2.5	R106	48,300	.5
10	R107	150,000	1.0
50	R108	800,000	1.0
250	R109	4 meg	1.5
500	R110	5 meg	1.5
1,000	R111	10 meg	2
5,000	(In Multiplier Kit MX-815/U)	100 meg	2

c. Checking A-C Voltage Ranges.

- (1) Turn the FUNCTION switch to the AC VOLTS position. Plug one test lead into the AC VOLTS jack and the other lead into the 2.5V jack on the right-hand side of the meter panel.
- (2) Apply 2.5 volts ac from Meter Test Set TS-682/GSM-1.
- (3) The meter reading should be accurate within plus or minus 4 percent.
- (4) Repeat the procedure for the remaining a-c ranges, using appropriate jack connections and applying suitable full-scale voltages. The accuracy on all ranges should be within plus or minus 4 percent, except for the 1,000-volt range, which should be within plus or minus 5 percent.
- (5) The same resistors used as multipliers for the 1,000-ohm-per-volt, d-c ranges are used for the a-c ranges. In addition, the following components are a part of the circuit when ac is measured:
 - (a) R121, a resistor of 1,300 ohms with a tolerance of plus or minus .5 percent.
 - (b) A101, an assembly which includes the rectifier and a preadjusted resistor network. If any part or parts of this unit are defective, the entire assembly should be replaced.

d. Checking Resistance Ranges.

- (1) Turn the FUNCTION switch to the OHMS position. Plug leads into the two OHMS jacks. Short the leads together, and rotate the OHMS ZERO ADJ knob until the pointer indicates zero ohms at each position of the range

switch. If the meter will not adjust to zero, check the batteries and rheostat R120.

- (2) Use Decade Resistor TS-679/U or fixed resistors known to be accurate within plus or minus 1 percent to check each resistance range at midscale value. The instrument should be accurate within plus or minus 3 percent of full-scale value on all scales.
- (3) The table below gives resistor values and tolerances.

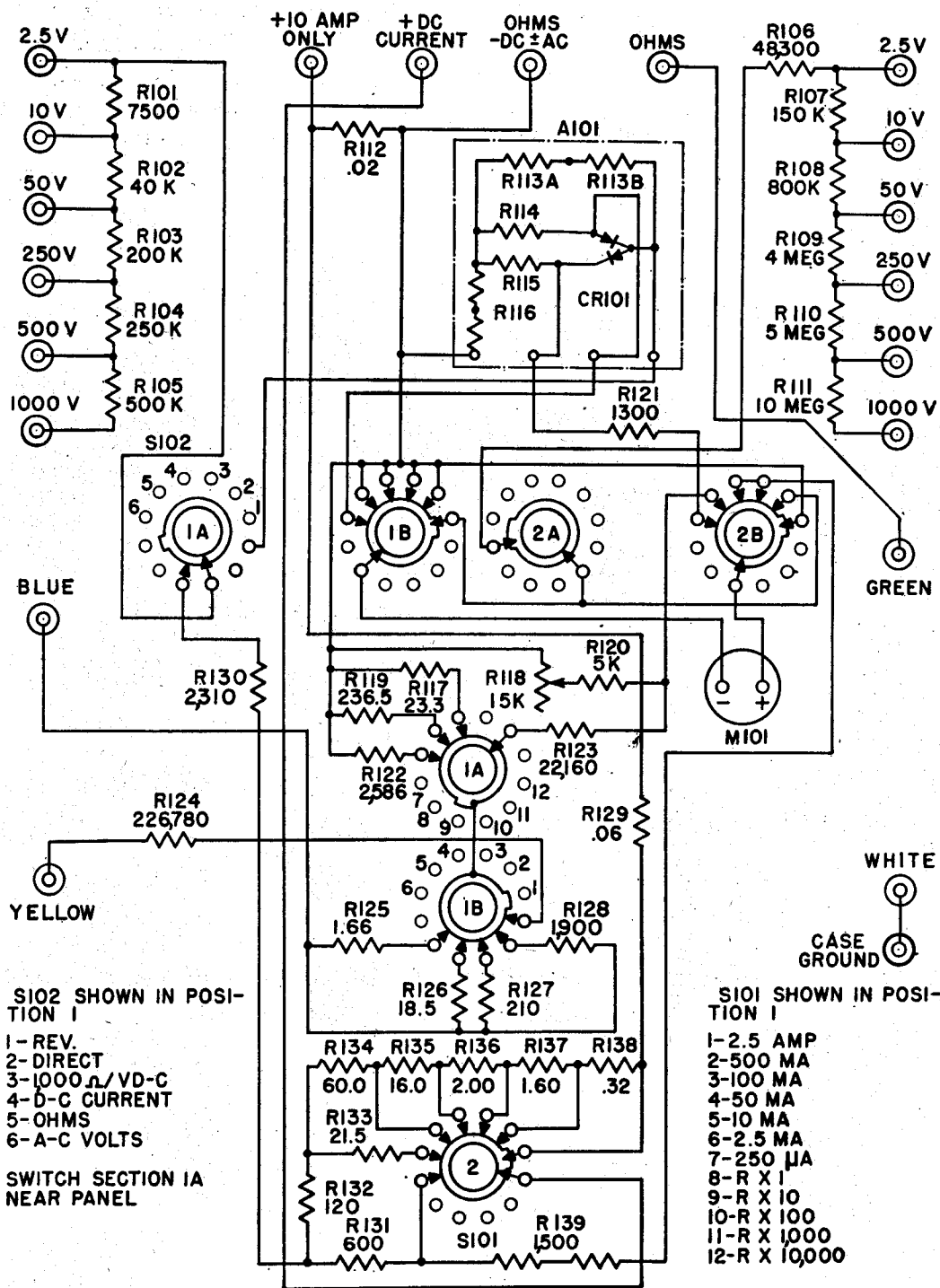
Range	Resistor	Resistance value (ohms)	Tolerance (%)
RX1 through RX1,000	R125	1.666	±.5
	R126	18.5	±.5
	R127	210	±.5
	R128	1,900	±.5
	R123	22,160	±.5
RX10,000	R123	22,160	±.5
	R124	226,780	±1.0
All	R118	15,000	±.5
	R120	5,000	±.5

e. Checking D-C Ranges.

- (1) Turn the FUNCTION switch to the DC CURRENT position. Plug the black test lead into the negative d-c jack. For ranges from 250 μ a to 2.5 amperes, plug the red lead into the +DC CURRENT jack.
- (2) Rotate the range switch to each current range, successively, and apply full-scale dc from Meter Test Set TS-682/GSM-1 for each range. All d-c ranges should be accurate within plus or minus 3 percent.
- (3) To check the 10-ampere range, plug the red lead into the jack marked ±10 AMP ONLY.
- (4) Different combinations of the same resistors are used for the various ranges; therefore, if an error in reading in excess of plus or minus 3 percent is observed, the simplest test procedure is to check the values of all resistors associated with the current ranges. The table below gives the resistance values and tolerances.

Resistor	Resistance value (ohms)	Tolerance (%)
R131	600	±.5
R132	120	±.5
R133	21.5	±.5
R134	60.0	±.5
R135	16.0	±.5

Resistor	Resistance value (ohms)	Tolerance (%)
R136	2.0	±.5
R137	1.6	±.5
R138	.32	±.5
R112	.02	±.5
R129	.06	±.5



NOTE: ALL RESISTORS ARE SHOWN IN OHMS
UNLESS OTHERWISE INDICATED

TM4700-71

Figure 59. Multimeter TS-352/U, schematic diagram.

54. Electronic Multimeter TS-505/U, TM 11-5511

(figs. 60 and 61)

a. Sensitivity. The sensitivity of the basic meter used in Electronic Multimeter TS-505/U is 1 ma dc for full-scale deflection.

b. Checking D-C Voltage Ranges.

- (1) Rotate the FUNCTION switch to the D.C. position, and allow 15 minutes for the equipment to warm up.
- (2) Adjust the meter to zero by rotating the ZERO ADJ control.
- (3) Connect one test lead between the COMMON binding post on Meter Test Set TS-682/GSM-1 and the COM-

MON binding post on the electronic multimeter. Use the alligator clips supplied to connect the d-c probe of the multimeter to the spade-lug end of the cord that has Plug PL-55 at the other end (part of the meter test set equipment). Apply the following voltages, successively, to check the accuracy of each d-c scale of the instrument: 2, 4, 10, 20, 40, 100, 200, 400, and 1,000 volts. The readings of the electronic multimeter should agree with those of the standard d-c meter within plus or minus 4 percent.

- (4) If an error in excess of 4 percent

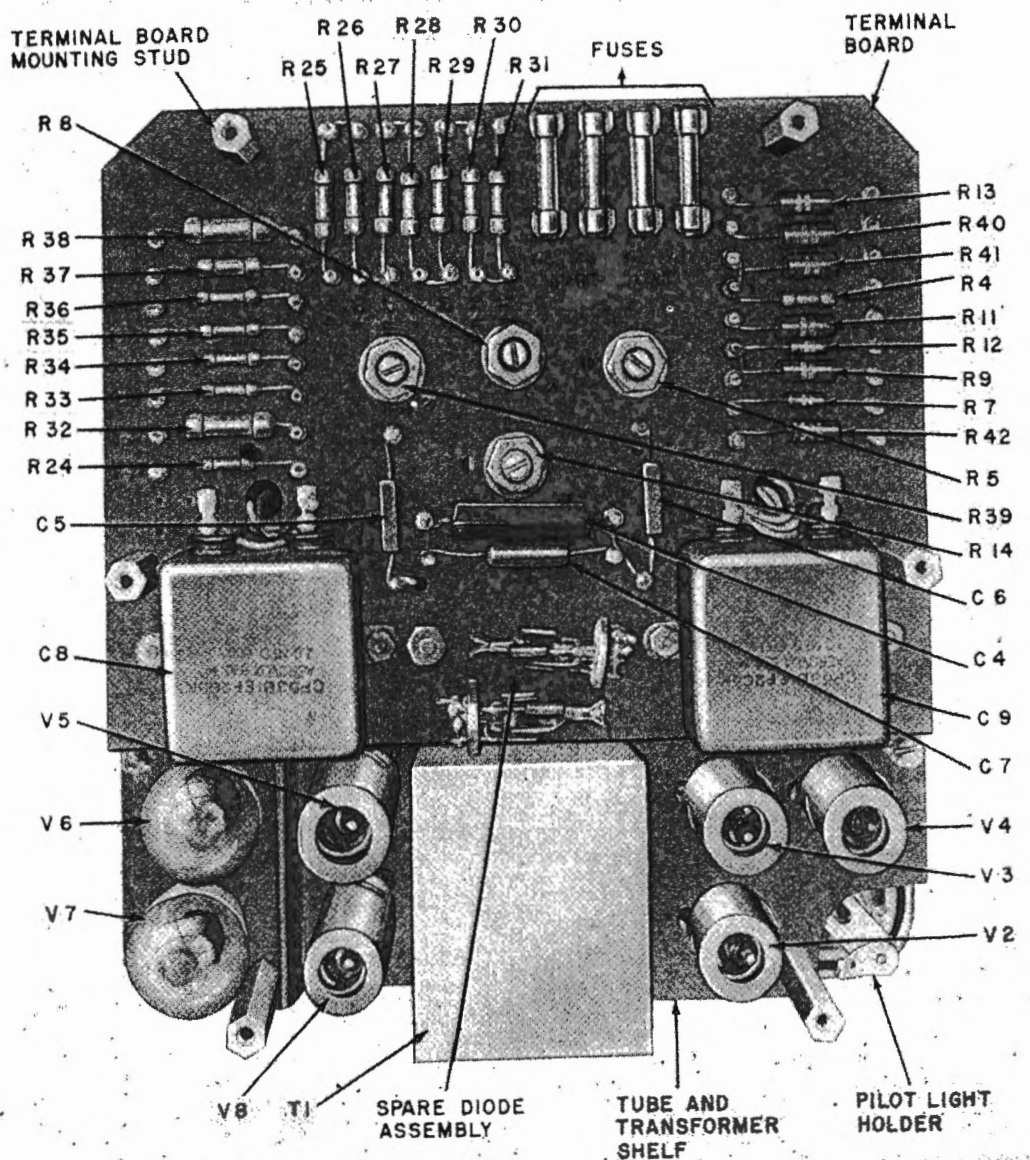
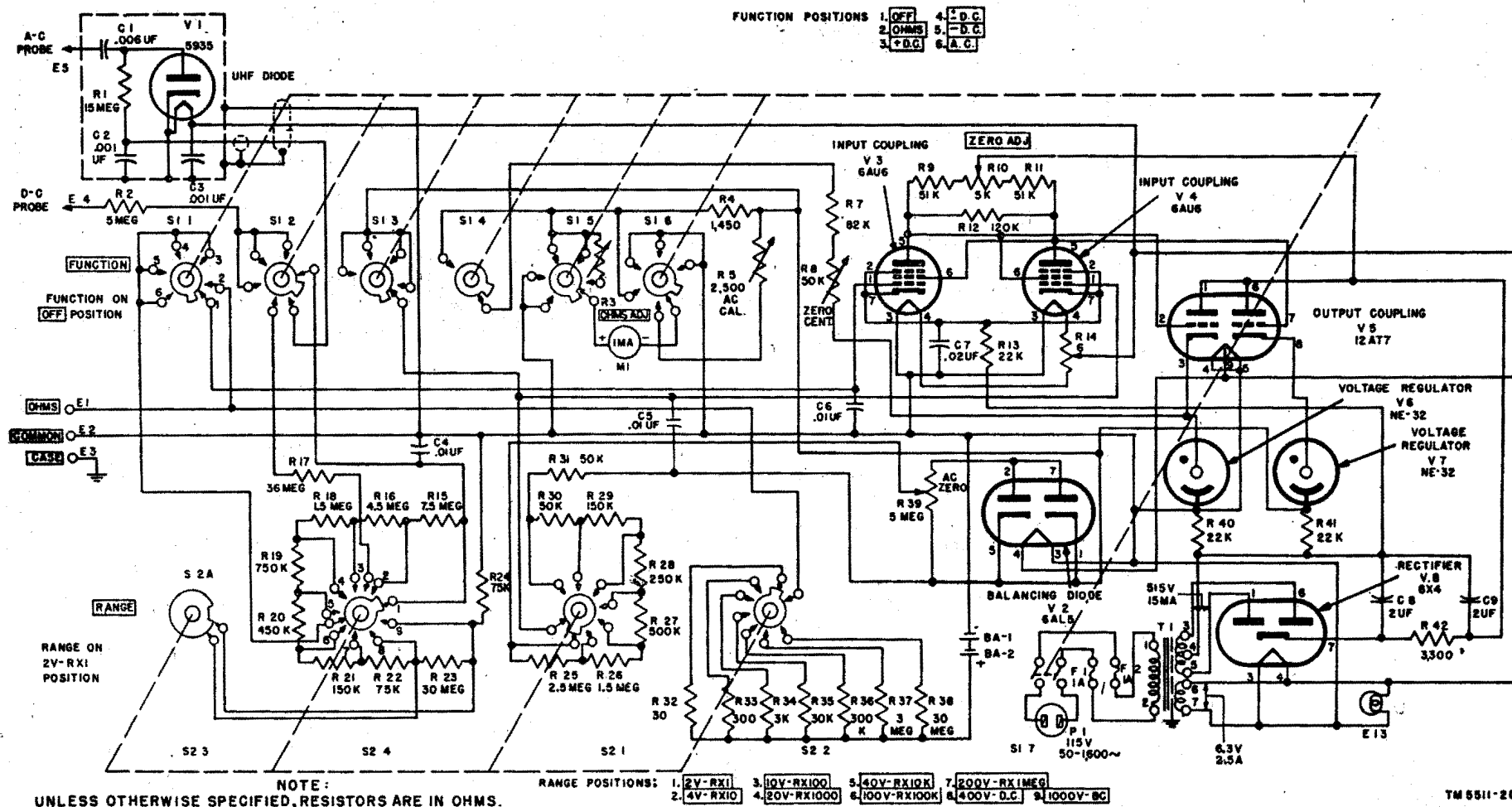


Figure 60. Electronic Multimeter TS-505/U, rear view, showing calibration resistors and adjustments.



TM 5511-20

Figure 61. Electronic Multimeter TS-505/U, schematic diagram.

exists, check the values of resistors R2, R4 and R15 through R24 (figs. 60 and 61). If there is an excessive error on the 2-volt range, check the accuracy of the amplifier (TM 11-5511) before checking the resistors.

c. Checking A-C Voltage Ranges.

- (1) Operate the FUNCTION switch to the A.C. position. Operate the RANGE switch to the 10V position.
- (2) Apply 10 volts plus or minus 1 percent at 400 cps to the a-c probe. In the absence of a 400-cps source, 60 cycles may be used. For calibration purposes, the test voltage must have less than .5 percent distortion.
- (3) Adjust resistor R5 until the meter pointer reads full-scale.
- (4) Repeat the procedure for the other ranges; be sure to apply appropriate voltages. The readings should be accurate within plus or minus 6 percent.
- (5) Tighten the locknut on resistor R5.

Be careful not to disturb the setting of the control.

d. Checking Resistance Ranges.

- (1) Rotate the FUNCTION switch to the OHMS position, and set the RANGE switch to the RX1 position. The meter should deflect up scale. Rotate the OHMS ADJ knob until the pointer indicates infinity. If full clockwise adjustment does not cause full-scale deflection, check Batteries BA-30.
- (2) Use Decade Resistor TS-679/U or resistors known to be accurate within plus or minus 1 percent to select values of resistance equal to one half the full-scale meter resistance marking, and to check the action and accuracy of each range of the meter.
- (3) If there is an error in excess of 4 percent of full scale, check the value of resistors R32 through R38 (fig. 61). The values should be accurate within plus or minus 1 percent.

Section III. TUBE TESTERS AND COMBINATION TUBE AND SET TESTERS

55. Tube Testers I-177 and I-177-A, TM 11-2627 (fig. 62).

a. Sensitivity. The sensitivity of the basic meter is 1.4 ma at 112 mv plus or minus 2 percent. The internal resistance of the meter is approximately 80 ohms.

b. Operational Checks. After completing the necessary repairs and calibration of the basic meter, make an operational check as follows:

- (1) Obtain several common tubes known to be in good condition. These should include triodes, remote and sharp cut-off pentodes, diodes, beam-power pentodes, and several multifunction tubes, as well as electron-ray indicator tubes.
- (2) Connect the tube tester to a suitable source of voltage; then set the controls and perform the quality test for each of the various tube types, as indicated by the chart attached to the tube tester.
- (3) If the indication for any tube is incorrect, use another tube of the same type,

and recheck. If several tubes that are known to be good give *replace* indications on the meter, make a parts check (c below).

c. Parts Check. Check resistors 40, 41, 43, 44, 45, 46, 48, 73, 74, 75, 76, 77, 78, and 79 (fig. 62). The values must be accurate within the following tolerances: 73, 74, and 77, plus or minus $\frac{1}{2}$ ohm; 76, plus or minus 1 ohm; 41, plus or minus 5 percent; 40, 48, and 75, plus or minus 10 percent; and 43, 44, 45, 78, and 79, plus or minus 15 percent.

56. Test Set I-157-A (Tube and Set Tester, Precision Model 920P), TM 11-1209 (fig. 63).

a. General Information. This test set is a combination instrument which uses a single meter with circuits and switching arrangements to perform the functions of a multimeter as well as a tube tester.

b. Sensitivity. The sensitivity of the basic meter is 400 μ a at 160 mv plus or minus 2 per-

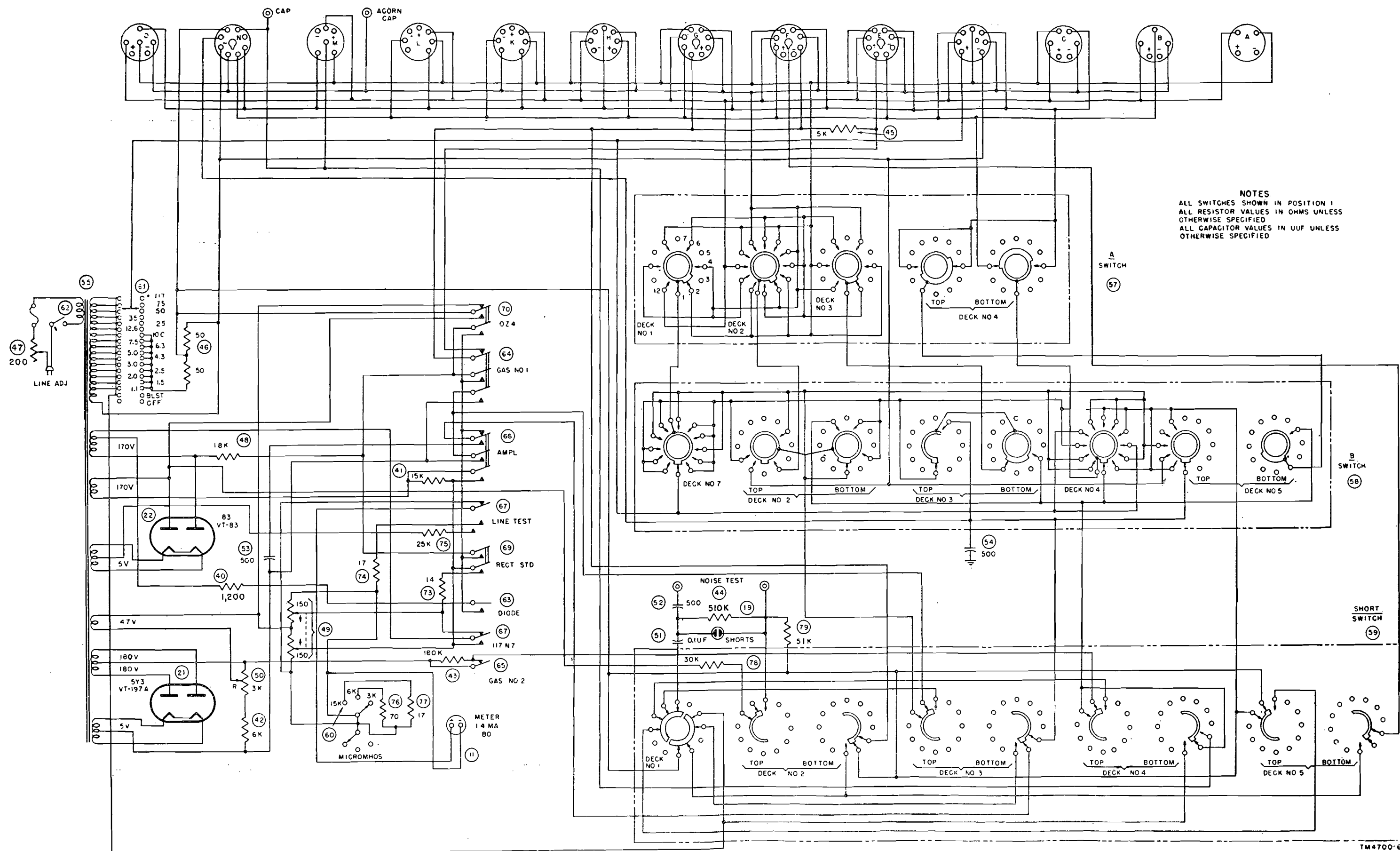


Figure 62. Tube Tester I-177, schematic diagram.

cent. The internal resistance of the meter is 400 ohms.

c. Checking D-C Voltage Ranges.

- (1) Set control A to the DC position.
- (2) Plug the test leads into the EXT. TEST jacks, and connect them to the appropriate cords of Meter Test Set TS-682/GSM-1.
- (3) Apply suitable voltages from the test set to obtain full-scale deflection of the meter, and check the 12-, 60-, 300-, 600-, 1,200-, and 3,000-volt scale of the instrument, successively.

Note. To read on the 600-volt range, multiply the 60-volt scale reading by 10; to read on the 1,200-volt range, multiply the 12-volt scale reading by 100; to read on the 3,000-volt range, multiply the 30-volt scale reading by 100.

- (4) The readings of Test Set I-157-A should agree with those of the standard d-c meter within plus or minus 5 percent.
- (5) If the readings disagree by more than 5 percent, check the values of resistors R15, R16, R17, R29, R30, R32, and R33 (fig. 63). The values should be accurate within plus or minus 1 percent. Resistor R32 shunts the meter for all d-c voltage ranges. *Do not adjust R32 unless all d-c voltage ranges are off calibration by the same percentage.*

d. Checking A-C Voltage Ranges.

- (1) Set control A to the AC position.
- (2) Repeat the procedure outlined in c(2) through (4) above.
- (3) If the readings disagree by more than plus or minus 5 percent, check the values of resistors R34 and R35 (fig. 63). Adjust R34 to calibrate the 12-volt range. *Do not adjust R35 unless all a-c ranges are off calibration by the same percentage.*

Note. Resistors R15, R16, R17, R29, and R30 are multipliers for the a-c as well as the d-c ranges. Large variations in the accuracy of the a-c ranges or failure of the meter to indicate may be caused by a defective meter rectifier. Replace the rectifier, and recheck the a-c ranges as outlined above.

e. Checking Current Ranges (DC).

- (1) Set control A to the DC position.

- (2) Plug the test leads into the EXT. TEST jacks for all current ranges except the 12-ampere range; for the 12-ampere range, plug the leads into the separate pin jacks, + and -12 AMPS.
- (3) Set the range switch and apply the proper current from Test Set TS-682/GSM-1 to check the accuracy of the following ranges at full scale: 1.2, 12, 120, and 600 ma. Leave the range switch in the 600 ma position, and change the test leads to the 12-ampere position. Apply 12 amperes from the standard, and check the meter for accuracy.
- (4) The readings should be accurate within plus or minus 5 percent. If they do not satisfy this tolerance, check the value of resistors R18 through R21 and R31 (fig. 63). The values of these resistors should be accurate within plus or minus 1 percent. Adjust R31 to calibrate the 12-ampere range; R18 for the 600-ma range; R19 for the 120-ma range; R20 for the 12-ma range; and R21 for the 1.2-ma range.

f. Checking Resistance Ranges. Check the low-resistance scale (400 ohms) ((1) through (4) below); then check the high-resistance scales ((5) through (10) below).

- (1) Set control A to the DC position.
- (2) Set control F to the 400 OHMS position, and rotate control C (ohms adjust control) to produce full-scale indication. Plug the test leads into the EXT. TEST jacks.
- (3) Use Decade Resistor TS-679/U or resistors known to be accurate within plus or minus 1 percent to check the meter with half-scale values of resistance.

Note. The 400-ohm range uses the shunt method of measuring resistance, and an immediate indication is obtained on the meter when the range selector is set to the 400-ohm position. If full-scale deflection is not obtained, check the 4½-volt battery.

- (4) The meter reading should be accurate within plus or minus 5 percent at mid-scale. If the reading is not within this tolerance, check the values of resistors R23 and R36 (fig. 63). Resistor R23

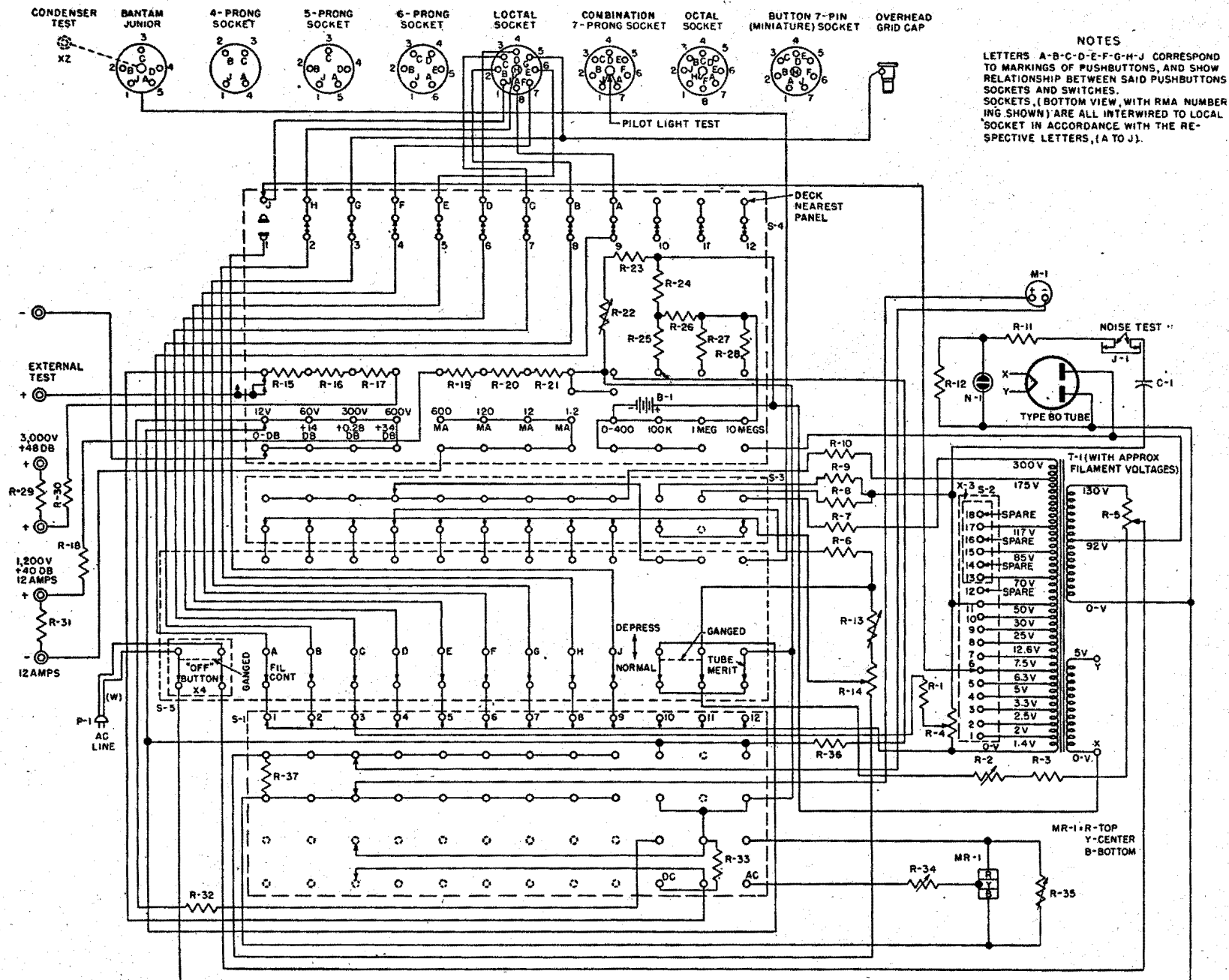


Figure 63. Test Set I-157-A, schematic diagram.

must be accurate within plus or minus 1 percent. Resistor R36 is shunted across the meter, and should be disconnected from the meter when its value is checked. Resistor R36 is adjusted to calibrate the meter on the 400-ohm range.

- (5) Set control F to the 100M position.
- (6) Connect the test leads together, and rotate control C to bring the meter pointer to exactly full-scale deflection.
- (7) Apply the test leads across a resistor whose value is within plus or minus 1 percent or half-scale value of the 100M range. The meter should read within plus or minus 5 percent of the value of the applied resistance. If an error in excess of plus or minus 5 percent exists, check the values of resistors R24 through R26 (fig. 63). The values of these resistors should be accurate within plus or minus 1 percent. Adjust R25 to calibrate the 100M range.
- (8) Check the 1 MEG resistance range as outlined in (5) through (7) above, use appropriate resistance values. If in-

accuracies are in excess of plus or minus 5 percent check the value of resistor R27 (fig. 63).

- (9) Voltage for the 10 MEG range is received from the internal power supply of the tester; therefore, the cord must be plugged into a suitable source of power. Full-scale deflection is obtained by adjusting the line control.
- (10) Apply half-scale resistance value plus or minus 1 percent and check the meter indication for accuracy. Calibrate if necessary, by adjusting R28 (fig. 63).

g. Checking Tube Tester. Follow the procedure given in paragraph 55b(1) through (3).

h. Checking Battery Tester. The battery tester differs from the d-c voltmeter in that it applies a load across the terminals of the battery under test and gives an indication of GOOD, REPLACE, or BAD, rather than a reading in volts. Check the battery test part of Test Set I-157-A by applying appropriate voltages from the standard and observing the indications on the meter.

Section IV. CAPACITY ANALYZERS AND CRYSTAL RECTIFIER TEST SETS

57. Capacity Analyzer ZM-3/U, TM 11-5043

(fig. 64).

a. Sensitivity. The sensitivity of the basic meter is 50 μ a at 250 mv, with a resistance of 5,000 ohms plus or minus 2 percent.

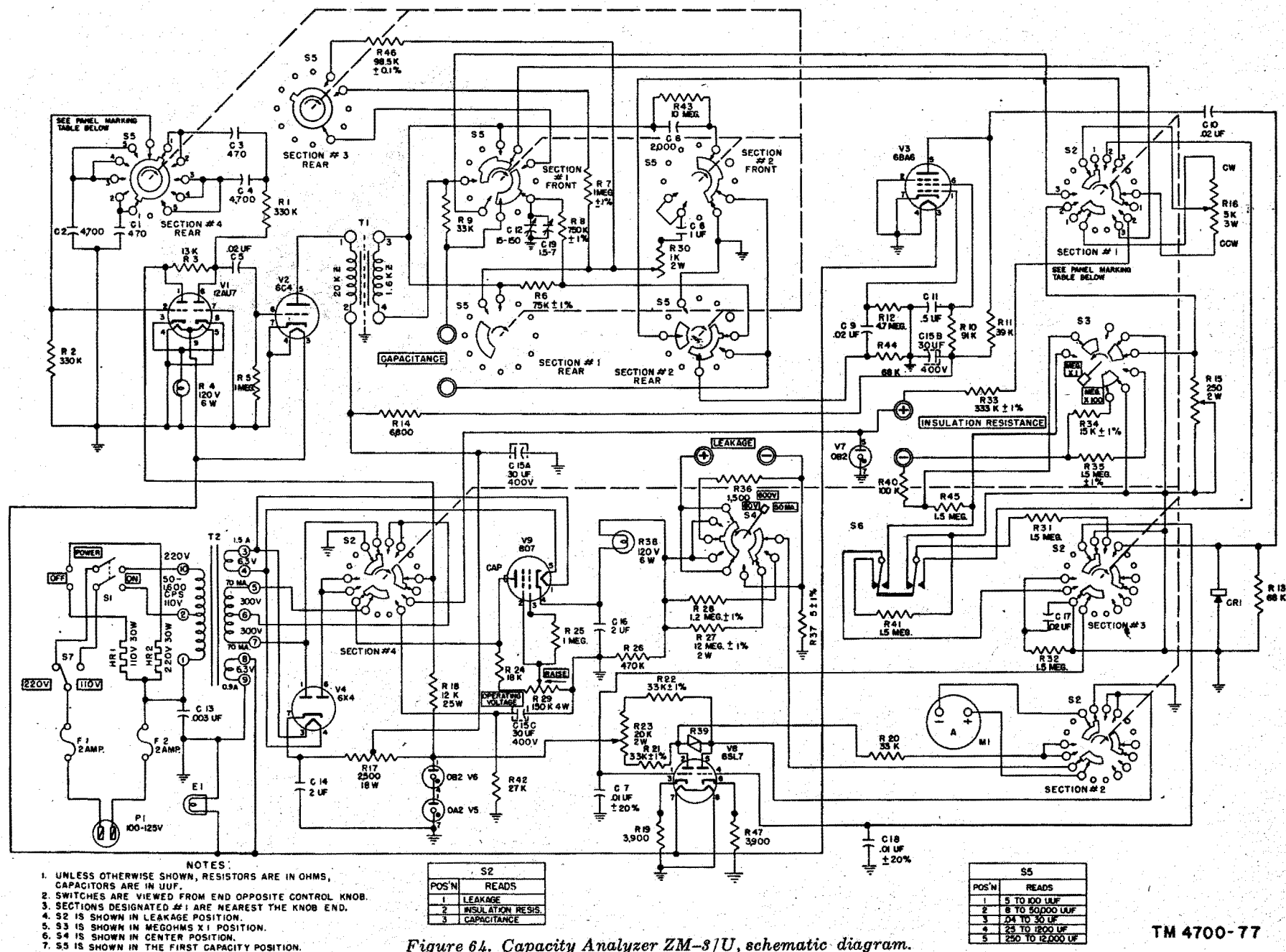
b. Calibration. The calibration of this instrument involves only variable resistor R16 and the dial drum, but the correction of any discrepancy involves disassembly of the entire drum assembly. To determine whether the drum dial is adjusted properly to control R16, proceed as follows:

- (1) Measure the total resistance of resistor R16 with Test Set I-49. *Do not use an ohmmeter.* Record the value.
- (2) Divide this value by 2, and adjust R16 until the resistance from the arm to one end of the control equals the quotient.

- (3) The drum dial now should indicate 2,000 $\mu\mu$ f (micromicrofarad) plus or minus 1 percent on the second capacitance range. If the indication is not within this tolerance, remove the dial assembly and make adjustments (TM 11-5043).

c. Checks for Accuracy Limits of Capacity Analyzer ZM-3/U. To check the accuracy of the various functions and ranges of the capacity analyzer, proceed as follows:

- (1) *Capacitance.* The capacitors have been calibrated on standard capacitance bridges with an accuracy of plus or minus .1 percent up to 1 μ f (microfarad), and plus or minus 1 percent from 1 μ f to 10,000 μ f. Use standard capacitors of the required accuracy (TM 11-5043) to check the capacitance ranges of the analyzer.



TM 4700-77

- (2) *Insulation resistance.* Use Decade Resistor TS-679/U up to 100,000 ohms, and Resistance Bridge ZM-9()/U above 100,000 ohms to test insulation resistance.
- (3) *Leakage.* Use Decade Resistor TS-679/U and Multimeter TS-352/U to determine the accuracy of leakage voltage and current indications with a variable load.
- (4) *Power factor.* The power-factor control is calibrated to within plus or minus 10 percent accuracy by means of a capacitor with a dissipation factor of less than .1, and a calibrated variable resistor that is set to give varying power factors from 0 to 50 percent from calculated values of series resistance.

Resistor	Resistance value (ohms)	Tolerance (%)
R101	100	±5
R102	500	±10
R103	900	±5
R104	100	±5
R105	300	±5
R106	600	±5

- (3) If the meter is defective and an exact replacement is not at hand, a standard 3½-inch American War Standard unit may be installed when the resistance of the unit is 100 ohms or less. When the resistance of the meter is less than 100 ohms, connect a suitable resistor in series with the meter to bring the total resistance to 100 ohms.

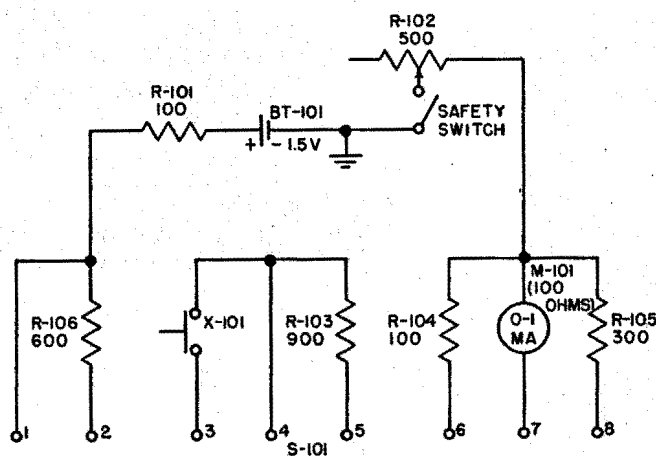
58. Crystal Rectifier Test Set TS-268/U, TM 11-1242

(fig. 65)

a. Sensitivity. The sensitivity of the basic meter is 1 ma, with a resistance of 100 ohms plus or minus 2 percent.

b. Operational Check. Rotate the selector clockwise to the first position. Adjust the MTR ADJ control for full-scale deflection. If the meter does not deflect to full scale, check parts as follows:

- (1) Check Battery BT101. If necessary, replace it.
- (2) Check the resistors; values should correspond with the values given in the following table:



POSITION	CONNECTIONS
OFF	1-2 3-8 4-7
1. MTR ADJ (FOR FWD AND BKWD RES)	2-3-4-5-7-8
2. FWD RES	2-3 4-7-8
3. BKWD RES	2-4 3-7-8
4. MTR ADJ (FOR BACK CUR)	1-2-4 3-6 5-7
5. BACK CUR	1-2-4 3-7 5-6

NOTES:
ALL RESISTOR VALUES IN OHMS
UNLESS OTHERWISE SPECIFIED

TM 4700-63

Figure 65. Crystal Rectifier Test Set TS-268/U, schematic diagram.

Section V. POWER METERS AND DYNAMOTOR TEST SETS

59. Output Meter TS-585A/U, TM 11-5017

(figs. 66 and 67)

a. Sensitivity. The sensitivity of the basic meter is 182 μ a at 63 mv, with a resistance of 346 ohms.

b. Calibration.

- (1) Obtain the following equipment for calibration of Output Meter TS-585A/U:

(a) Audio Oscillator TS-382A/U, or equivalent.

- (b) Electronic Multimeter TS-505/U, or equivalent.
- (c) A general-purpose screw driver (Sig C stock No. 6R15694).
- (2) Connect the oscillator output to the binding posts of Output Meter TS-585A/U. Observe the ground-to-ground rule when making these connections.
- (3) Connect the multimeter to the binding posts of Output Meter TS-585A/U.
- (4) Connect the oscillator and the multimeter to an appropriate power source.
- (5) Set the output control of the oscillator for minimum output, turn the power on, and set the frequency for 1,000 cps.
- (6) Set the meter multiplier control knob of Output Meter TS-585A/U at position 10, and set the impedance control knob to 300 ohms (position 30 in the X10 bracket).
- (7) Set the multimeter controls for the 0- to 10-volt a-c range and turn on the power. Let the equipment warm up for about 15 minutes.
- (8) Turn the output control of the oscillator until the multimeter indicates exactly 6 volts. The output meter should read within 3 divisions of 12 on the MILLIWATTS scale. If the meter does not read within these limits, adjust rheostat R3 (fig. 66). *Do not adjust the rheostat excessively, or the 300-ohm calibration will be out of tolerance.* If adjustment of the rheostat does not correct the error in the meter indication, check the impedance network (Z2, fig. 67).
- (9) To calibrate the 20,000-ohm impedance range, proceed as follows:
 - (a) Set the meter multiplier control knob at position 1.
 - (b) Set the impedance control knob for 20,000 ohms (position 200 in the X100 bracket).
 - (c) Set the controls of Electronic Multimeter TS-505/U to read 15.5 volts ac.
 - (d) Turn the output control of the oscillator until the multimeter reads 15.5 volts. The output meter should read within $2\frac{1}{2}$ divisions of 12 on the

MILLIWATTS scale. If the meter does not read within these limits, adjust rheostat R3 (fig. 67) *moderately*. If adjustment of the rheostat does not bring the meter reading within tolerance limits, check the impedance control (Z1).

60. Test Sets I-199 and I-199-A, TM 11-2604

(fig. 68)

a. Sensitivity. Two meters are used in this instrument. Except for calibration, they are identical. Their sensitivity is 1 ma, resistance is 27 ohms, and they are accurate to within plus or minus 1 percent, with a 30-mv drop.

b. Calibration Information. After accuracy of the meters has been checked, it is necessary to check only the values of the various components (fig. 68) for tolerance.

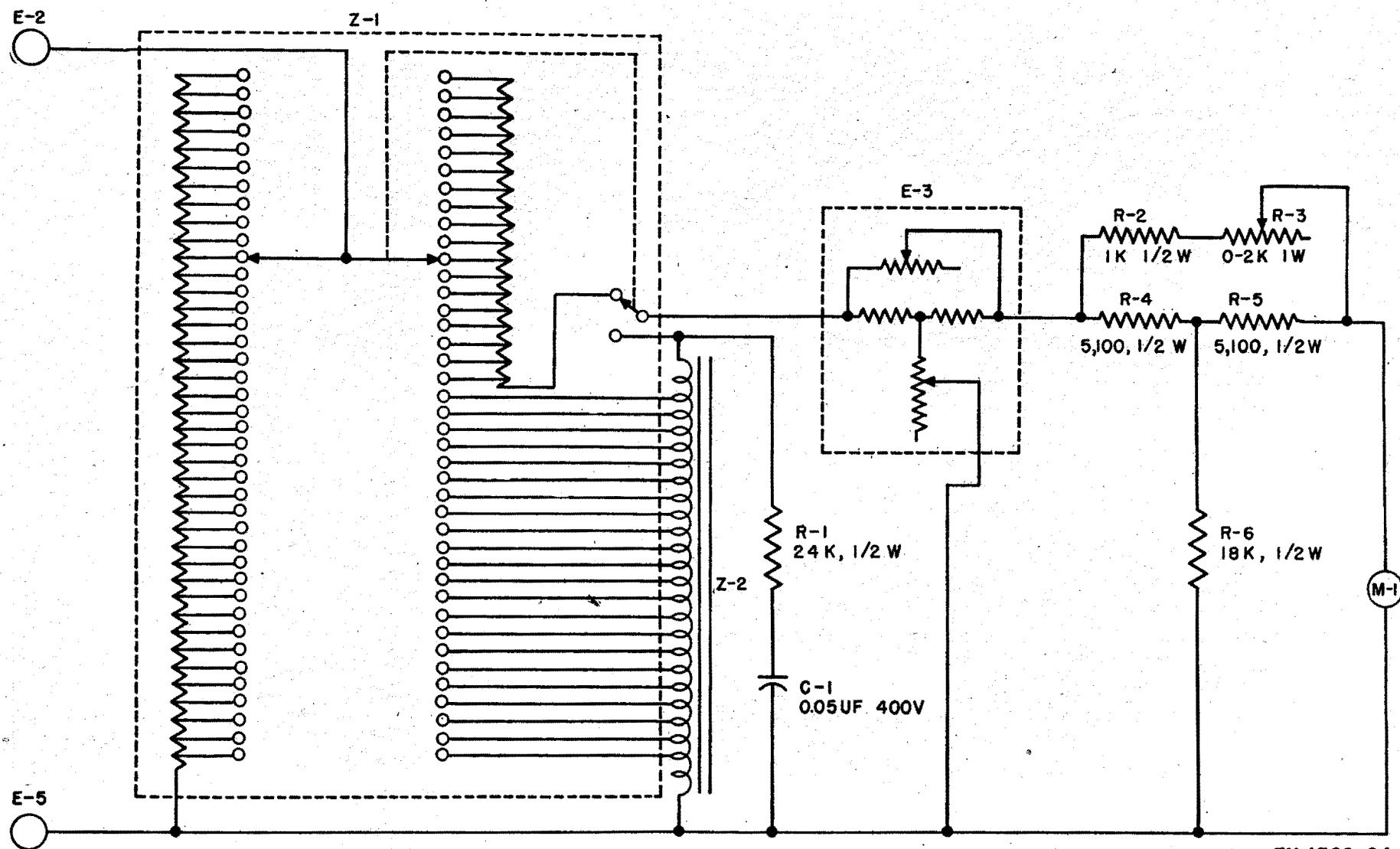
c. Parts Check.

- (1) Meter shunt S1 is an assembly of resistors made up of R2, R3, R4, and R5. If any one of these resistors is defective, replace the entire shunt.
- (2) Resistor cards 1, 2, and 3 are matched in pairs for an accuracy of plus or minus 3 percent. If R8, R9, R10, R11, R12, or RE1 is defective, replace card 1. If R14, R15, R16, R19, R20, R21, R22, or RE2 is defective, replace card 2. If R17, R18, or R23 is defective, replace card 3.
- (3) Capacitors C1 and C2 are used as a d-c isolation device and a ripple filter, respectively, and do not affect the calibration of the meters. They should, however, be tested for leakage and capacitance. Capacitor C1 is an oil-filled, 2,000 volts d-c, 1- μ f (plus or minus 20 percent) capacitor. Capacitor C2 is an oil-filled, 2,000 volts d-c, 4- μ f (plus or minus 20 percent) capacitor.

61. Frequency Meter SCR-211-(), TM 11-300

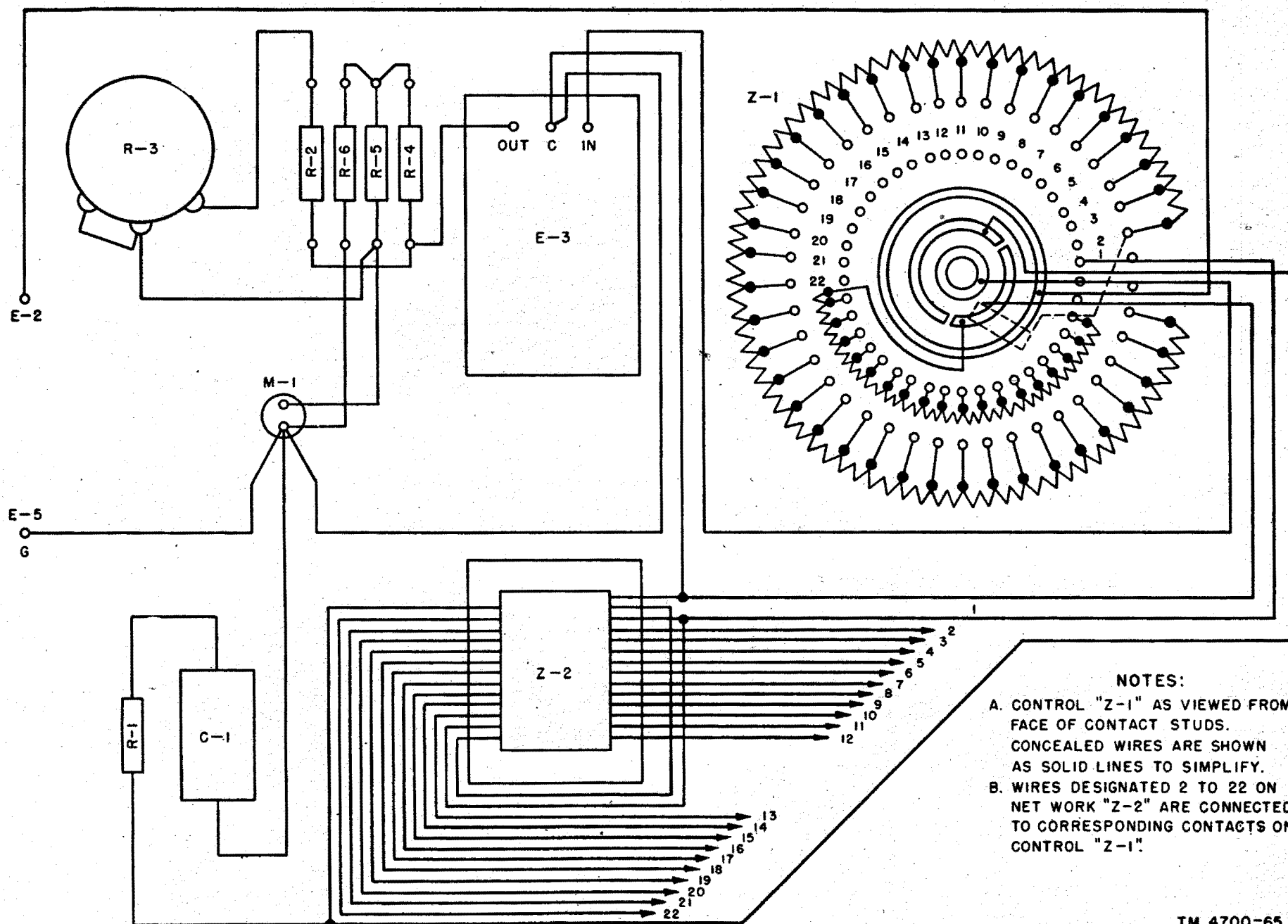
(fig. 69)

a. Components. Frequency Meter SCR-211-() is composed of Frequency Meter BC-221-(),



TM 4700-64

Figure 66. Output Meter TS-585A/U, schematic diagram.



NOTES:

- A. CONTROL "Z-1" AS VIEWED FROM FACE OF CONTACT STUDS. CONCEALED WIRES ARE SHOWN AS SOLID LINES TO SIMPLIFY.
- B. WIRES DESIGNATED 2 TO 22 ON NET WORK "Z-2" ARE CONNECTED TO CORRESPONDING CONTACTS ON CONTROL "Z-1".

TM 4700-65

Figure 67. Output Meter TS-585A/U, wiring diagram.

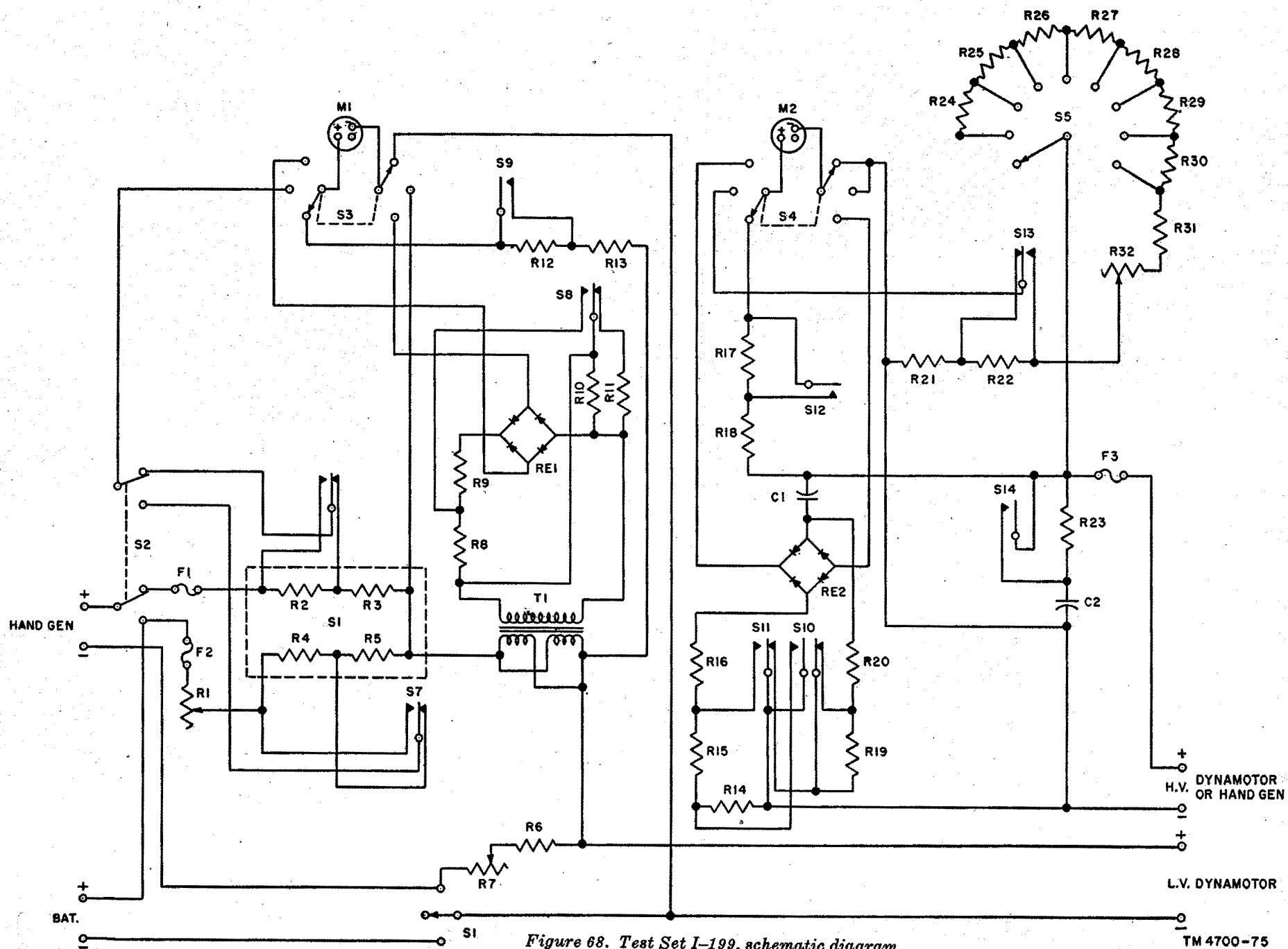


Figure 68. Test Set I-199, schematic diagram.

TM 4700-75

as well as batteries, test leads, and calibration charts. The frequency meter is the calibrated part of the equipment. No meters are used in this equipment.

b. *Calibration.* If the frequency meter has been damaged, or if adjustment of the crystal padder capacitor has been changed, reset it by using a standard frequency transmission and a radio receiver. The National Bureau of Standards standard frequency station WWV broadcasts 24 hours a day on two frequencies, 5 mc (megacycles) and 10 mc. During daylight hours, WWV also broadcasts on a frequency of 15 mc for Washington, D. C. Every hour on the hour, and every 5 minutes thereafter for 1 minute, the carriers are not modulated except for identification. Between unmodulated periods, the carriers are modulated simultaneously by a 440-cycle sine wave and a 4,000-cycle sine wave. The signals from this station are a primary standard, and can be used to set the frequency of the crystal oscillator in Frequency Meter BC-221-() as follows:

- (1) Remove the chassis from the case, and connect the batteries with clip leads.
- (2) Plug in a headset, throw the POWER switch to ON, and turn the CRYSTAL switch to ON.
- (3) Allow the frequency meter to warm up for 10 to 15 minutes.
- (4) Tune a receiver, such as Receiver BC-342, BC-312, R-62/PR, R-80/PR, R-

210/U, or SCR-704, to one of the standard frequencies mentioned above. Do not use the receiver beat-frequency oscillator, except to locate the signal. Turn off the beat-frequency oscillator before attempting to adjust the crystal oscillator frequency.

- (5) Couple the output of the frequency meter to the antenna of the receiver. If the crystal oscillator is functioning, an audio tone will be heard in the headset. To obtain a zero beat between the frequency meter and WWV, adjust the crystal padder capacitor.

Note. Make this adjustment with an insulated screw driver. If a metal screw driver is used, the crystal may stop oscillating each time the crystal padder capacitor is touched.

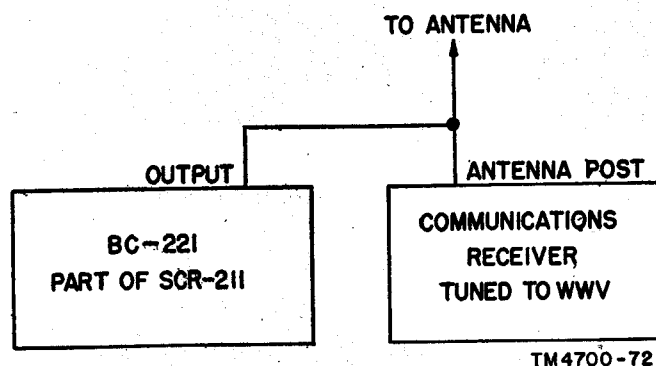


Figure 69. Block diagram of equipment set up for calibration of frequency meter.

CHAPTER 5

CALIBRATION OF EXPOSURE METERS

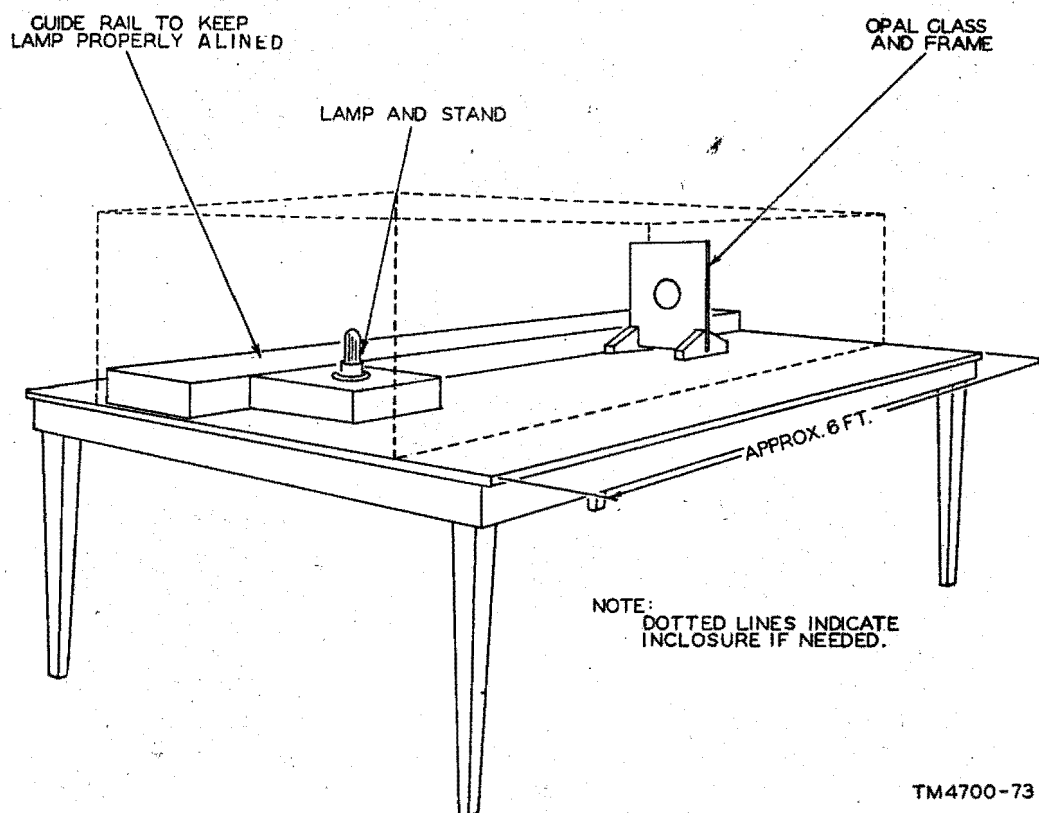
62. General

The photographic exposure meters covered in this chapter are of the photoelectric type; each consists of a light-sensitive cell and a meter. The light-sensitive (photovoltaic) cell is usually of the selenium type, and the meter is usually a microammeter. No polarizing voltage is necessary, and output is sufficient to operate the meter directly without amplification. Since the meter is a conventional type, necessary repairs are performed as for any conventional meter. The scale of the meter usually is calibrated in arbitrary values. Balance is extremely important in this type of instrument because, in nor-

mal use, the meter may be held in any position. General instructions for the use of exposure meters and disassembly procedures and lists of replaceable parts are contained in TM 11-2356, Exposure Meters PH-260 and PH-260-A.

63. Calibration Procedure

Exposure meters are calibrated by the comparison method. A known value of light is permitted to enter the window of the meter under calibration, and the meter is calibrated by magnetization. Meters and photocells are usually available in matched pairs for replacement. A



TM4700-73

Figure 70. Equipment set up for calibration of exposure meter.

convenient source of adjustable light (a through j below) may be fabricated.

a. Obtain the following materials:

- (1) A 750-watt T-12 projection lamp, with medium base, designed for 120-volt service.
- (2) A socket capable of carrying at least 1,000 watts.

- (3) A sheet of crown-flashed opal glass, 5 by 7 inches in size.
- (4) A sheet of opaque paper, preferably black.
- (5) A variac.
- (6) Wood to make blocks, as indicated in figure 70.

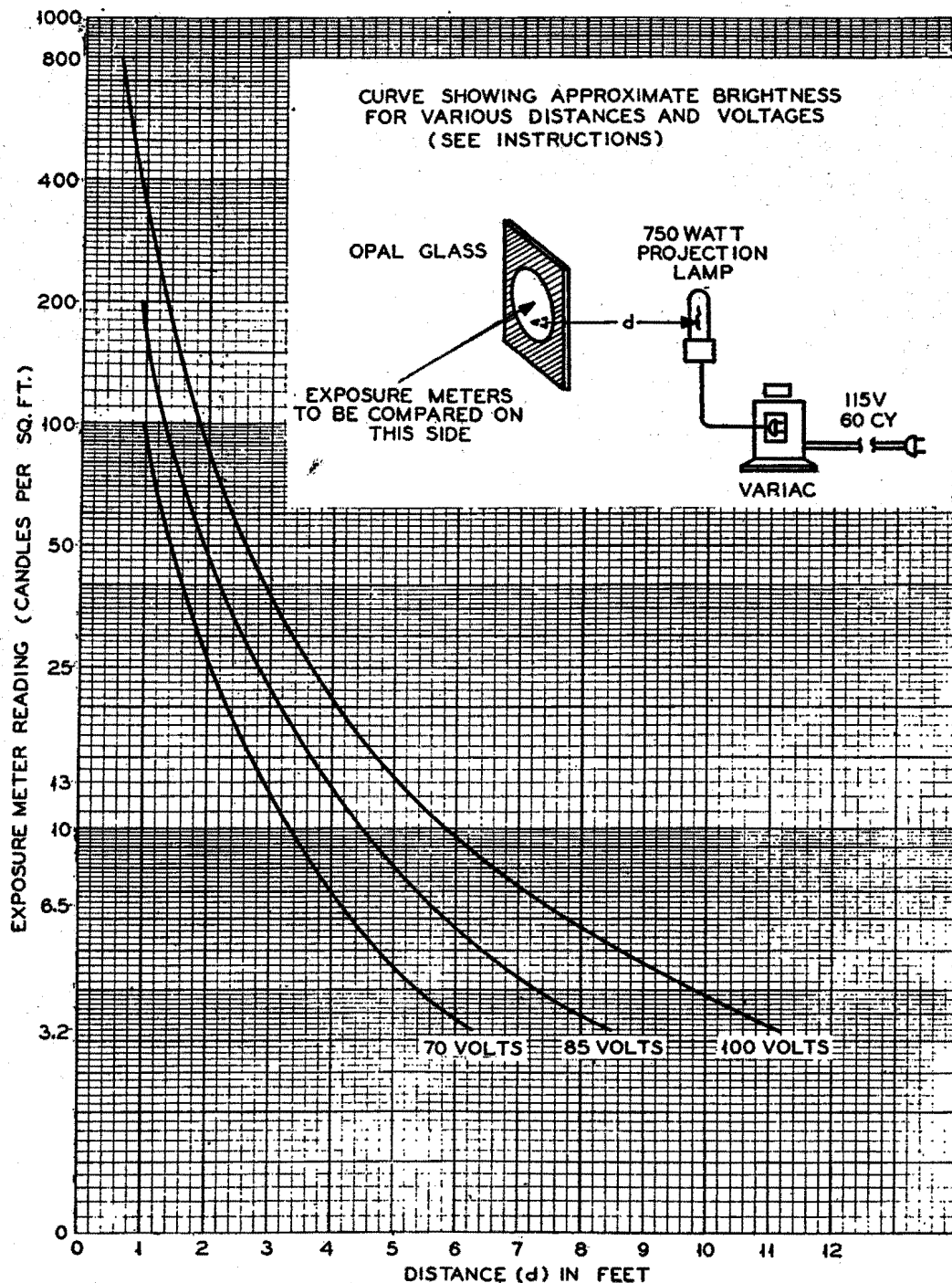


Figure 71. Light values and response curves for exposure meter calibration set up.

b. Cut a 3-inch circle from the center of the opaque paper.

c. If the equipment cannot be set up in a darkened room, it should be inclosed in an elongated box (fig. 70) to minimize the effects of stray light and to reduce the possibility of shadows on the opal glass.

d. Place the lamp in the socket and use No. 14 wire to connect the variac output (and a voltmeter, if desired) to the socket.

e. Set up the opal glass with the opal side toward the lamp and with the mask on the reverse side.

f. Move the lamp along the wooden strip until

the distance is about correct for the required brightness at the voltage selected.

g. Connect the variac to a power source and adjust the voltage to a convenient value, as determined from the graph in figure 71.

h. Place the standard exposure meter against the mask, with the cell centered on the 3-inch window.

i. Adjust the variac until the standard meter gives a reading at the center of the desired block.

j. Remove the standard meter and insert the meter to be calibrated. If the meter reads too high it should be demagnetized; if too low, it must be remagnetized.

APPENDIX I

REFERENCES

Note. For availability of items listed, check SR 310-20-3 for field manuals and JANAP's. Check SR 310-20-4 for technical manuals, technical bulletins, supply bulletins, modification work orders, and changes. Check SR 310-20-5 for Army regulations and special regulations.

1. Regulations

a. Army.

- AR 380-5 Safeguarding Military Information.
- AR 750-5 Maintenance Responsibilities and Shop Operation.

b. Special.

- SR 310-20-3 Index of Training Publications (Field Manuals, Training Circulars, Firing Tables and Charts, Army Training Programs, Mobilization Training Programs, Army Training Tests, Graphic Training Aids, Joint Army-Navy-Air Force Publications, Combined Communications Board Publications, and Army Communications Publications).
- SR 310-20-4 Index of Technical Manuals, Technical Regulations, Technical Bulletins, Supply Bulletins, Lubrication Orders, Modification Work Orders, Tables of Organization and Equipment, Reduction Tables, Tables of Allowances, Tables of Organization, and Tables of Equipment.

- SR 310-20-5 Index of Administrative Publications (Army Regulations, Special Regulations, Joint Army-Air Force Adjustment Regulations, General Orders, Bulletins, Circulars, Commercial Traffic Bulletins, Joint Procurement Circulars, Department of the Army Pamphlets, and ASF Manuals).

- SR 700-45-5 Unsatisfactory Equipment Report (Reports Control Symbol CSGLD-247).

- SR 745-45-5/ } Report of Damaged or Improper Shipment (Reports Control Symbols CSGLD-66 (Army) and AF-MC-U2 (Air Force)).
- AFR 71-4 }

2. Supply Publications

- SB 11-6 Dry Battery Supply Data.
- SB 11-47 Preparation and Submission of Requisitions for Signal Corps Supplies.
- SB 11-100 Serviceability Standards for Signal Equipment in Hands of Troops.

3. Technical Manuals on Test Equipment

- TM 11-300 Frequency Meter Sets SCR-211-().
- TM 11-1209 Test Set I-157-A. (Tube and Set Tester, Precision Model 920P)

TM 11-1239 Voltmeters TS-363/U and TS-363A/U.
 TM 11-1242 Crystal Rectifier Test Set TS-268/U.
 TM 11-2017 Test Sets TS-26/TSM and TS-26A/TSM.
 TM 11-2019 Test Set I-49.
 TM 11-2535A Meter Test Equipment AN/GSM-1B.
 TM 11-2356 Exposure Meters PH-260 and PH-260-A.
 TM 11-2604 Test Sets I-199 and I-199-A.
 TM 11-2627 Tube Testers I-177 and I-177-A.
 TM 11-5043 Capacity Analyzer ZM-3/U.
 TM 11-5511 Electronic Multimeter TS-505/U.
 TM 11-5017 Output Meters TS-585A/U and TS-585B/U.
 TM 11-5500 Multimeter TS-297/U.
 TM 11-5520 Decade Resistor TS-679/U.
 TM 11-5527 Multimeter TS-352/U.

4. Painting, Preserving, Maintenance, and Lubrication

TB SIG 13 Moistureproofing and Fungiproofing Signal Corps Equipment.

TB SIG 66 Winter Maintenance of Signal Equipment.
 TB SIG 69 Lubrication of Ground Signal Equipment.
 TB SIG 72 Tropical Maintenance of Ground Signal Equipment.
 TB SIG 75 Desert Maintenance of Ground Signal Equipment.
 TB SIG 123 Preventive Maintenance Practices for Ground Signal Equipment.

5. Other Publications

FM 24-5 Signal Communications.
 TB SIG 25 Preventive Maintenance of Power Cords.
 TB SIG 219 Operation of Signal Equipment at Low Temperatures.
 TM 11-430 Batteries for Signal Communication. Except Those Pertaining to Aircraft.
 TM 11-453 Shop Work.
 TM 11-455 Radio Fundamentals.
 TM 11-661 Electrical Fundamentals (Direct Current).
 TM 11-681 Electrical Fundamentals (Alternating Current).

APPENDIX II

MISCELLANEOUS INFORMATION

1. Formulas

a. Ohm's Law.

$$E = IR \quad R = \frac{E}{I} \quad I = \frac{E}{R}$$

R = resistance in ohms.

I = current in amperes.

E = pressure in volts.

b. *Frequency (Ac)*. (Dc is considered as having a frequency of 0 cycles per second.)

$$F = P \frac{S}{120}$$

F = frequency in cps.

P = number of poles in machine

S = speed of machine in rpm.

120 = a constant to change alternations per minute to cps.

c. Number of Poles in a Machine.

$$P = F \frac{120}{S}$$

P = number of poles in machine.

F = frequency in cps.

S = Speed of machine in rpm.

120 = a constant to change alternations per minute to cps.

d. Resistors in Parallel.

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \dots$$

R_T = total resistance of resistors in parallel.

R_1, R_2, R_3 , etc. = values of the individual resistors.

This formula may be stated as follows: The reciprocal of the total resistance is equal to the sum of the reciprocals of the individual resistors. When only two resistors are connected in parallel, the following simplified formula may be used: $R_T = \frac{R_1 R_2}{R_1 + R_2}$, which expresses the

total resistance as equal to the product of the two resistors divided by the sum of the two resistors.

e. Shunt Calculation.

$$R_S = \frac{R_M}{(N-1)}$$

R_S = value of shunt in ohms.

R_M = resistance of the meter in ohms.

N = multiplying factor. (The multiplying factor is determined by dividing the basic current range of the meter into the range to which the meter is to be shifted.)

f. Multiplier Calculations.

$$R_S = R_M (N-1)$$

R_S = value of multiplier in ohms.

R_M = resistance of the meter in ohms.

N = multiplying factor. (The multiplying factor is determined by dividing the basic voltage range of the meter into the range to which the meter is to be shifted.)

g. Resistor in Series.

$$R_T = R_1 + R_2 + R_3 \dots$$

R_T = total resistance of the resistors in series.

R_1, R_2, R_3 , etc. = values of individual resistors.

h. *Series-Parallel Combinations*. To find the total series resistance, calculate the total resistance of each parallel circuit and add the totals together.

i. Power Calculations.

$$P = EI = \frac{E^2}{R} = I^2 R$$

P = power in watts.

E = pressure in volts.

I = current in amperes.

R = resistance in ohms.

j. Ohmmeter Calculations.

$$R_x = R_c \left(\frac{I - I_1}{I_2} \right)$$

R_x = unknown resistance.

R_c = total circuit resistance with R_x shorted.

I_1 = current when resistance is shorted.

I_2 = total current when R_x is in the circuit.

k. Shunt-Type Ohmmeter Calculations.

$$R_x = R_m \left(\frac{I_2}{I_1 - I_2} \right)$$

R_x = unknown resistance.

R_m = resistance of the meter.

I_1 = current in circuit without R_x across the meter.

I_2 = current in circuit with R_x across the meter.

This type of designation is essentially the same as the American War Standard type designation, and it is being set up for all components of radio apparatus.

a—The letters (MR) designate an electrical indicating instrument.

b—These two figures (25) designate the case, size, type, and material of an instrument. Various case sizes and materials are designated as follows: 24—2½-inch molded-phenolic case, round, flush-mounting, panel-type instrument, calibrated for use on a steel panel .09 inch thick. 25—2½-inch molded-phenolic case, round, flush-mounting, panel-type instrument, calibrated for use on a nonmagnetic panel. 34—3½-inch molded-phenolic case, flush-mounting, panel-type instrument, calibrated for use on a steel

2. Military (JAN) Specifications for Electrical Indicating Instruments

a	b	c	d	e	f
MR	25	F	001	DC	MA
Components electrical indicating instrument	Case size, type, and material	Dial and pointer color scheme	Number of units shown by full-scale deflection	Kind of current for which the instrument is designed.	Units indicated by instrument

panel .09 inch thick. 35—3½-inch, molded-phenolic case, round, flush-mounting, panel-type instrument, calibrated for use on a nonmagnetic panel.

c—This single letter (F) designates the color scheme of the pointer and of the dial background and markings. Letters for various color schemes are as follows: B—white markings and pointer, black background. F—fluorescent markings and pointer, black background. S—self-luminous markings and pointer, black background. W—black markings and pointer, white background.

d—These three figures (001) designate the number of units shown by full-scale deflection of the instrument. Where the full scale is less than three figures, zeros are inserted to the left to fill out to three figures. Where the letter R is used between two figures in this group, it represents a decimal point. Thus, a 1½-volt voltmeter would be designated 1R5.

e—These two letters (DC) designate the kind of current for which the instrument is designed. Combinations of letters for the various kinds of current are as follows:

AC—Alternating current (60 cps, nominal frequency).

AD—AC—DC (Alternating current, 25 to 125 cps only).

AE—Alternating current (800 cps, nominal frequency).

AF—Alternating current (400 cps, nominal frequency).

AR—Alternating current, rectifier type.

DC—Direct current.

RF—Radio frequency, conventional scale.

RL—Radio frequency, linear expanded scale.

The letters SPEC are used in place of the letters specified in groups e and f for special instruments such as zero-center ammeters, milliammeters, microammeters, and various special instruments. Such instruments arbitrarily are assigned serial numbers to be used in place of the three figures called for in group d above.

f—These two letters (MA) designate the electrical units which the instrument indicates. Combinations of letters for various units are as follows:

UA—Microamperes.

MA—Milliamperes.
 AA—Amperes.
 KA—Kiloamperes.
 MV—Millivolts.
 VV—Volts.
 KV—Kilovolts.
 DB—Decibels.
 VU—Volume units (volume-level indicators).
 WW—Watts.
 KW—Kilowatts.
 GW—Megowatts.

Example: In the illustration above, the type designation MR25F001DCMA signifies:

- a—An electrical indicating instrument.
- b—A 2½-inch molded-phenolic case, round, flush-mounting, panel-type.
- c—A black background dial with fluorescent marking and pointer.
- d—A full-scale deflection of 1.
- e—It is designed to indicate dc.
- f—It is a milliammeter.

3. Construction of Expedient Magnet Charger

If a magnet charger is not available, meter magnets may be charged by using the following materials and method:

a. Obtain Battery BB-46 (or any equivalent battery or batteries), 3 feet of copper-braided bonding strap about 3/8-inch wide (Sig C stock No. 1F6B1-4, 1F6B1-5, 1F6C1-6, or 1F6C1-8), and a roll of friction tape. When more than one battery is used, or where the ampere-hour capacity of the battery is small, connect in parallel.

b. Insulate the bonding strap by wrapping 2 feet of its length with friction tape; leave 6 inches of bare strap at each end. Overlap each turn of tape to insure good electrical insulation. Then wrap the insulated strap around the meter magnet; use as many turns as possible to form a coil. When bonding strap is not available, use large copper wire with low resistance and high current-carrying capacity.

c. Test the polarity of the meter magnet with a small compass. Remember that the *north pole of the compass needle* (dark-colored) is attracted to the *south pole of the magnet*. Mark the north pole of the magnet with chalk or crayon. Use the right-hand rule to determine the direction in which current in the coil should flow to produce the necessary polarity. To do this, grasp the coil in the right hand, with the extended thumb pointing toward the north pole of the magnet. The fingers now point in the direction in which the current must flow around the coil. Note which end of the strap the current must enter and use a clamp to attach this end firmly to the *positive* terminal of the battery.

d. Before starting the charging process, place a keeper across the pole pieces of the meter magnet.

e. Touch the free end of the bonding strap *momentarily* to the *negative* terminal of the battery; one or two applications usually will suffice. Do not hold the strap in contact with the terminal for any length of time, because prolonged contact will injure the battery. Touch the strap to the terminal for only an instant each time.

DECIBEL CONVERSION CHART

POWER LEVEL DB	POWER RATIO TO 0 DB	POWER .006 WATT AT 0 DB. WATTS	VOLTAGE RATIO TO 0 DB	VOLTS -- BASED ON .006 WATT AT 0 DB IN	
				500 OHMS	600 OHMS
-10	0.1000	0.0006000	0.31623	0.5477	.6000
-9	0.1259	0.0007553	0.35481	0.6145	.6732
-8	0.1585	0.0009509	0.39811	0.6895	.7554
-7	0.1995	0.0011972	0.44668	0.7737	.8475
-6	0.2512	0.0015071	0.50119	0.8681	.9509
-5	0.3162	0.0018975	0.56234	0.9740	1.0670
-4	0.3981	0.0023886	0.63096	1.0928	1.1972
-3	0.5012	0.0030071	0.70795	1.2262	1.3433
-2	0.6310	0.0037857	0.79433	1.3758	1.5071
-1	0.7943	0.0047660	0.89125	1.5437	1.6910
0	1.0000	0.0060000	1.00000	1.7321	1.8974
+1	1.2589	0.0075535	1.1220	1.9434	2.1289
+2	1.5849	0.0095093	1.2589	2.1805	2.3886
+3	1.9953	0.0119716	1.4125	2.4466	2.6801
+4	2.5119	0.0150713	1.5849	2.7451	3.0071
+5	3.1623	0.0189747	1.7783	3.0801	3.3741
+6	3.9811	0.0238865	1.9953	3.4559	3.7867
+7	5.0119	0.030071	2.2387	3.8776	4.2477
+8	6.3096	0.037857	2.5119	4.3507	4.7660
+9	7.9433	0.047660	2.8184	4.8816	5.3475
10	10.0000	0.060000	3.1623	5.4772	6.0000
11	12.589	0.075535	3.5481	6.1455	6.7321
12	15.849	0.095093	3.9811	6.8954	7.5536
13	19.953	0.119716	4.4668	7.7368	8.4752
14	25.119	0.150713	5.0119	8.6808	9.5094
15	31.623	0.189747	5.6234	9.7400	10.670
16	39.811	0.238865	6.3096	10.9285	11.972
17	50.119	0.30071	7.0795	12.2620	13.433
18	63.096	0.37857	7.9433	13.7582	15.071
19	79.433	0.47660	8.9125	15.4369	16.910
20	100.000	0.60000	10.0000	17.3205	18.974
21	125.89	0.75535	11.220	19.434	21.289
22	158.49	0.95093	12.589	21.805	23.886
23	199.53	1.19716	14.125	24.466	26.801
24	251.19	1.50713	15.849	27.451	30.071
25	316.23	1.89747	17.783	30.801	33.741
26	398.11	2.38865	19.953	34.559	37.867
27	501.19	3.0071	22.387	38.776	42.477
28	630.96	3.7857	25.119	43.507	47.660
29	794.33	4.7660	28.184	48.816	53.475
30	1000.00	6.0000	31.623	54.772	60.000
31	1258.9	7.5535	35.481	61.455	67.321
32	1584.9	9.5093	39.811	68.954	75.536
33	1995.3	11.9716	44.668	77.368	84.752
34	2511.9	15.0713	50.119	86.808	95.094
35	3162.3	18.9747	56.234	97.400	106.70
36	3981.1	23.8865	63.096	109.285	119.72
37	5011.9	30.071	70.795	122.620	134.33
38	6309.6	37.857	79.433	137.582	150.71
39	7943.3	47.660	89.125	154.369	169.10
40	10000.0	60.000	100.000	173.205	189.74
41	12589.2	75.535	112.20	194.34	212.89
42	15848.9	95.093	125.89	218.05	238.86
43	19952.6	119.716	141.25	244.66	268.01
44	25118.9	150.713	158.49	274.51	300.71
45	31622.8	189.747	177.83	308.01	337.41
46	39810.7	238.865	199.53	345.59	378.67
47	50118.7	300.71	223.87	387.76	424.77
48	63095.7	378.57	251.19	435.07	476.60
49	79432.7	476.60	281.84	488.16	534.75
50	100000.0	600.00	316.25	547.72	600.00

TL 11082S

Figure 72. Decibel conversion chart.

APPENDIX III

GLOSSARY

Accuracy—When specifying the accuracy of an electrical indicating instrument, the limit of error at any point of the scale shall be expressed as a percentage of the full-scale value, unless otherwise specified for a particular type of instrument. When the zero is at a point other than at one end of the scale, the sum of the full-scale readings to the right and to the left of the zero point shall be used as the full-scale value.

Ammeter—An instrument calibrated in amperes and used to measure current in an electrical circuit. An ammeter normally is connected in series with the circuit.

Arbitrary-scale instrument—An instrument calibrated to read values which are not expressed in terms of the units actually read. Thus, an arbitrary-scale voltmeter would be calibrated in units other than volts (such as degrees centigrade, and foot-candles).

Current circuit of an instrument—The current circuit of an instrument is that winding of the instrument proper which carries the current to be measured, a definite fraction of it, or a current dependent on it.

Damping—The retarding force used to bring about steady indication of the meter pointer. There are two general classes of damped motion: periodic, in which the pointer oscillates about the rest position before stopping, and aperiodic, in which the pointer makes one direct excursion and comes to rest without overshooting the rest position. Critical damping is damping between periodic and aperiodic.

Decibel—A unit used to express logarithmically the ratio between two powers existing at two points; the number of decibels denoting such a ratio is 10 times the logarithm to the base 10 of the ratio. The decibel measures gain

or attenuation in power, voltage, or current between different circuits or different parts of the same circuit.

Decibel meter—An instrument used to measure the integrated mean of a complex waveform representing a signal, a variable frequency, or a noise. The instrument is calibrated in decibels above or below an arbitrary zero power level, represented by the resultant voltage when such a power is dissipated in a load of specified impedance.

Dustproof instrument—An instrument so well constructed, protected, or treated that dust cannot enter its case and interfere with its operation.

Electrodynamic (electrodynamometer) instrument—An instrument whose operation depends on the electromagnetic force resulting from currents in one or more moving coils acting upon the electromagnetic force produced by the currents in one or more fixed coils.

Electrostatic instrument—An instrument whose operation depends on the forces of attraction and repulsion between bodies charged with electricity.

Electrothermic instrument—An instrument whose operation depends on the heating effect of an electric current. Two distinct types are used: the expansion type, including the hot-wire and hot-strap type instruments, and the thermocouple type, in which one or more thermocouples, heated directly or indirectly by the passage of a current, supply dc which flows through the coil of a suitable d-c mechanism, such as a meter of the permanent-magnet, moving-coil type.

Frequency meter—An instrument calibrated in cycles per second and designed to measure the frequency of low-frequency ac. Also, an

instrument which contains a standard calibrated, radio-frequency generator, a mixer circuit, and a detector and uses the zero-beat method to determine the frequency of a signal.

Frequency variation meter (frequency meter)—An instrument calibrated to read, in cycles or percent, variations from a standard frequency (when the frequency is normal, the reading is zero).

Galvanometer—An instrument for indicating or measuring a minute electric current by means of the electromagnetic forces set up as a result of the current.

Induction instrument—An instrument in which the torque is produced by the action of fixed coils on moving conducting parts (such as disks, and drums, etc.) that carry currents produced by electromagnetic induction.

Instrument—A device which measures the value of the quantity under observation. The term *instrument* is used to include not only the instrument proper, but also any necessary associated apparatus, such as shunts, shunt leads, resistors, reactors, capacitors, or instrument transformers.

Instrument proper—The instrument proper is the meter mechanism and scale in the case; it includes all parts (such as resistors, and shunts) built into the case or nonremovably attached to it. For example: A 500-ampere d-c ammeter consists of the instrument proper (which may be essentially a millivoltmeter), together with a 500-ampere shunt and a pair of shunt leads. A wattmeter consists of the instrument proper (essentially a 5-ampere, 110-volt wattmeter), together with a current transformer and a potential transformer. The term *instrument* usually denotes a complete test set, whereas the term *meter* denotes a single-function device, such as a panel meter.

Jewels—Materials used for instrument pivots. Precious gems, usually sapphires, normally are used in this application, but other gems with a hardness equal to or greater than sapphires are equally acceptable. For certain applications, other materials, such as very hard glass, are used satisfactorily to replace precious gems.

Kiloammeter—An instrument calibrated in kiloamperes (1 kiloampere equals 1,000 amperes) and designed to measure the current in a circuit.

Kilovoltmeter—An instrument calibrated in kilovolts (1 kilovolt equals 1,000 volts) and designed to measure the voltage in a circuit.

Kilowattmeter—An instrument calibrated in kilowatts (1 kilowatt equals 1,000 watts) and designed to measure the power in a circuit.

Light meter, or exposure meter—An instrument for measuring the intensity of illumination (either direct light from the source or reflected light from an object or area). In the photovoltaic type, operation depends on the current generated by a photoelectric cell when light strikes it. This type of instrument usually is calibrated in arbitrary units, such as foot-candles, which may be converted into lens openings and shutter speeds.

Measurement range (of scales)—The measurement range is that part of the indicating range within which the requirement for accuracy must be met.

Mechanism—The mechanical and electrical arrangement used to produce and control the motion of the reading indicator. It includes all the essential parts, but does not include the base, scale, cover, or any parts (such as series resistors or shunts) whose function is to make the indicated value of the measured quantity agree with the actual value. Also known as the movement.

Megowattmeter—An instrument calibrated in megowatts (1 megowatt equals 1,000,000 watts) and designed to measure the power in a circuit.

Microammeter—An instrument calibrated in microamperes (1 ampere equals 1,000,000 microamperes) and designed to measure the current in a circuit.

Milliammeter—An instrument calibrated in milliamperes (1 ampere equals 1,000 milliamperes) and designed to measure the current in a circuit.

Millivoltmeter—An instrument calibrated in millivolts (1 volt equals 1,000 millivolts) and designed to measure the voltage in a circuit. When used with an external shunt, a millivoltmeter measures d-c amperes.

Modulation meter—An instrument designed to indicate the percentage of modulation of the output of a modulated radio transmitter, with respect to complete (100-percent) modulation.

Moistureproof instrument—An instrument constructed, protected, or treated so that its operation is not hampered by the entrance of moisture into its case, or so that moisture cannot enter its case.

Moving element—The reading indicator and the parts that move it. Also known as the movement, moving coil, or moving-iron vane.

Moving-iron-vane instrument—An instrument in which the movement of one or several pieces of soft iron is caused by the magnetic field of a fixed coil or coil system. Various forms of this instrument (plunger, vane, repulsion) are distinguished chiefly by differences in mechanical features of construction.

Multimeter—An instrument composed of an instrument proper, switches, multipliers, rectifiers, vacuum tubes and associated circuits; it may be used to measure several different electrical characteristics, such as current, voltage, and resistance.

Multiplier—A series resistor used to extend the range of a voltmeter beyond the particular value for which the basic meter is designed.

Mutual conductance meter—An instrument designed to indicate the mutual conductance of the vacuum tube.

Noise meter—An instrument for measuring noise volumes in comparison with a standard sound level, usually the threshold value. The ratio usually is indicated on a decibel meter used in connection with the device.

Ohmmeter—An instrument designed to measure the electrical resistance of a circuit. It usually is calibrated in units, tens, hundreds, and thousands of ohms. When designed to measure very high resistances, it is usually calibrated in megohms.

Permanent-magnet moving-coil instrument—An instrument that has a coil which moves within the field of a permanent magnet.

Power-factor meter—An instrument designed to measure the phase relationship between voltage and current in an a-c circuit. The instrument is calibrated in terms of the cosine of the angle by which the current lags or leads the voltage.

Pyrometer—An instrument designed to measure high temperatures. A voltage is generated at the junction of two dissimilar metals by the presence of the temperature to be read. This voltage is measured on a meter calibrated in degrees of temperature (centigrade, Fahrenheit, or other arbitrary values).

Radio-frequency instrument—Generally, any instrument designed to operate at 20 kilocycles per second or higher.

Range of an instrument—A designation assigned to indicate the maximum value of a quantity which can be measured; usually the full-scale value. In certain special instruments both minimum and maximum values are given.

Rating (circuit) of instrument—The maximum current or voltage level to which an instrument may be subjected without damage.

Ratio meter—An instrument designed to indicate the ratio between two voltages or currents.

Reactor—A reactor is a device that may be inductive, capacitive, or a combination of both; it is used in a meter circuit to adjust the phase relation between voltage and current. In meter work, reactances usually have a long time constant.

Rectifier instrument—A combination of a d-c sensitive instrument and a means of rectifying an ac or voltage to be measured.

Response—The rapidity, usually in seconds, with which the pointer of an instrument comes to rest after a change in the value of the quantity being measured.

Revolution indicator—An instrument designed to measure (usually by mechanical means) in revolutions per minute the speed of a rotating machine.

Scale length—The scale length is the lineal distance over which the pointer can move from one end of the complete scale to the other. In knife-edge pointers and other types which extend beyond the scale division marks, the excursion of the pointer is considered to end at the outer end of the shortest scale-division marks.

Self-contained instrument—An instrument into which all necessary auxiliary equipment is built or to which it is fixed permanently.

Series resistor—A resistor placed in series with the voltage circuit of an instrument to limit the current through the instrument and extend its range in volts.

Shunt—A resistor connected in parallel with a measuring device to extend its current range.

Shunt leads—The conductors which connect the current circuit of an instrument to the shunt; they normally are calibrated for use with a specified instrument.

Temperature indicator—An instrument designed to measure temperature by electrical means. The temperature-sensitive element is usually an embedded resistance coil whose resistance changes in proportion to temperature changes. Its range is usually lower than that of the pyrometer, and it is more sensitive to small variations in temperature.

Temperature influence—Temperature influence is the percentage change in the full-scale value indication of an instrument, caused by a change in room temperature of plus or minus 10° from a reference level.

Thermionic instrument—An instrument in which vacuum-tube circuits are employed to measure electrical quantities. It is also referred to as electronic multimeter and VTVM (vacuum-tube voltmeter).

Thermocouple—A device using two joined dissimilar metals which, when heated, generate a voltage proportional to the difference in temperature between the hot and cold junctions.

Thyratron tube—A gas-filled, hot-cathode, triode tube in which the plate current is controlled by the potential on the grid until the tube fires.

Volt-capacitance meter—A combination instrument for measuring voltage and capacitance.

Volt-ohm-milliammeter—A combination instrument for measuring voltage, resistance, and current. This type of instrument uses fixed and variable resistance and switches in appropriate circuits to perform the particular function desired.

Voltage circuit of instrument—The voltage circuit of an instrument is that winding of an instrument to which is applied the voltage to be measured, a definite fraction of it, or a voltage dependent on it.

Voltammeter—An instrument that measures both volts and amperes.

Voltmeter—An instrument designed to measure the pressure in volts in an electrical circuit.

Watertight (submersible) instrument—A watertight (submersible) instrument is mounted in a case that will withstand complete immersion in a tank containing sufficient water to cover all parts to a depth of at least 3 feet. After 1 hour, there should be no visible trace of penetration of water into the interior.

Watt-hour meter—An instrument designed to measure the power in an electrical circuit in watts, integrated over a period of time in hours.

Wattmeter—An instrument designed to measure the true power in an electrical circuit.

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